Universidad Autónoma de Madrid

Ph.D. on Economics and management of innovation

Economics Department

Essays on market failures and finance of innovation in Spain and Colombia

Edgard Alberto Méndez Morales

Advisors: Asunción López López and Juan Carlos Salazar Elena

Madrid, June 2017

Essays on market failures and finance of innovation in Spain and Colombia

Tesis del programa de Economía y Gestión de la Innovación

Doctorando: Edgard Alberto Méndez Morales

Resumen de la tesis

Durante el último siglo, la economía de la innovación ha tomado una gran relevancia en los estudios sobre crecimiento económico. Para los estudiosos de la economía de la innovación el crecimiento es generado por los incrementos en productividad de las compañías que a su vez generan mejores niveles de productividad a nivel agregado. Este hecho llevaría a pensar que los países, regiones y empresas a nivel mundial estarían volcados en la inversión en investigación, desarrollo e innovación (I+D+i), sin embargo, existen grandes diferencias con las cifras a nivel agregado percibidas a nivel mundial especialmente desde el punto de vista privado.

De tal forma, en los países menos desarrollados, la inversión en I+D+i es escasa si se le compara con otros países desarrollados, y desde la economía evolutiva se ha sugerido que estas diferencias en los niveles de inversión privada se deben en primer lugar a imperfecciones en los mercados que son más fuertes en estos países, pero también a diferencias en el entramado institucional para la innovación, es decir, los llamados Sistemas Nacionales de Innovación (SIN). En términos generales, estas falencias de los mercados y de los sistemas de innovación hacen que el nivel privado de inversión en I+D+i sea inferior al deseado y es necesario, de tal forma, investigar las causas e implicaciones de dichos factores especialmente en países menos desarrollados en los cuales se ha prestado poca o nula atención a estas problemáticas en el pasado.

Esta tesis tiene como objetivo fundamental determinar cuáles son las fuentes de financiación y las particularidades de las actividades innovadoras de pequeñas empresas que enfrentan impedimentos a la innovación en Colombia y España. De igual forma, la tesis contesta otras preguntas de investigación en cada uno de los capítulos de la misma y que están relacionadas con el momento del proceso de innovación en el cuál las empresas perciben las barreras a la innovación, la estructura de capital de las empresas con mayores

impedimentos para recaudar fondos y los efectos que tienen los subsidios de innovación en las pequeñas empresas innovadoras.

La tesis fue desarrollada en 5 capítulos en los cuales se da respuesta a los anteriores interrogantes; para esto se utilizaron microdatos de las encuestas de innovación de España y Colombia. En el caso de España se utilizó la encuesta PITEC con datos entre 2005 y 2013 para realizar los capítulos 2 y 4 de la tesis; estos capítulos están relacionados con la fase del proceso de innovación en el que se encuentra una empresa y su percepción de impedimentos a la innovación. De igual forma, la encuesta PITEC para España se utilizó para determinar los efectos que los subsidios a la innovación de forma puntual y recurrente tienen en pequeñas y grandes empresas de país en el largo plazo. Para el caso de la encuesta de innovación colombiana (EDIT) se usaron datos 2008 y 2009; esta encuesta posee la particularidad de preguntar a las compañías las fuentes de financiación utilizadas para sus procesos de innovación (fondos propios, bancos, fuentes de capital, subsidios públicos y otras fuentes de menor relevancia) y fue determinante para la realización del capítulo 3 de la tesis.

En todos los capítulos se realizaron modelos econométricos para dar cuenta de la validez de los resultados y se utilizaron metodologías como modelos probit de panel, modelos probit multivariados y modelos de diferencia en diferencia condicionada (CDID). Los capítulos se desarrollaron previendo que los resultados de los mismos pudiesen ser publicados en el futuro en revistas revisadas por pares académicos y contó con la participación de los Doctores Asunción López y Juan Carlos Salazar como coautores de los capítulos 2 y 4, así como con la participación en forma de consejeros del Doctor Florentino Malaver y la Profesora Marisela Vargas de la Pontificia Universidad Javeriana en el caso del capítulo 3. De igual forma, la tesis cuenta con un capítulo introductorio para contextualizar los avances en el campo de investigación a la fecha y un capítulo de conclusiones en el que se proponen directrices de política derivadas de los resultados de la investigación, así como futuras líneas de investigación por la cuales el doctorando espera continuar su carrera.

La tesis es novedosa en el sentido que aporta soluciones para algunos vacíos teóricos anteriores y la generación de amplias recomendaciones de política pública relacionadas con la financiación de la innovación; en primer lugar, es la primera vez que se realiza un estudio sobre impedimentos a la innovación teniendo en cuenta un espectro más amplio del

proceso, es decir, que no va únicamente hasta la generación del producto o servicio, sino que además comprende los impedimentos percibidos en la fase de comercialización de las innovaciones. De esta manera, se da una reinterpretación a la forma en que las empresas perciben estos impedimentos y se encuentra que las empresas que comercializan efectivamente sus innovaciones son aquellas que no los perciben de manera fuerte. Desde el punto de vista de la política pública esto genera la posibilidad de tener subsidios de innovación que no vayan exclusivamente hasta la generación de los productos o servicios innovadores, sino que comprendan también la comercialización de los mismos.

En segundo lugar, la tesis encuentra que la estructura de capital (fuentes de financiación) propuesta en la literatura reciente, no aplica a países en países en vía de desarrollo como Colombia. En este caso, se encuentra que en Colombia las empresas innovadoras se financian en un orden jerárquico que comprende fondos propios como mayor fuente de financiación seguido por bancos, fondos gubernamentales y en último lugar por fuentes de capital. Esto contradice la literatura reciente dado que se supone que las empresas innovadoras utilizan las fuentes de capital antes que las fuentes bancarias dadas sus particularidades de riesgo. En la tesis se propone que las causas de este comportamiento son en primer lugar el tipo de empresas usadas en la literatura tradicional (grandes empresas que cotizan en bolsa) que no necesariamente son las que sufren de grandes restricciones financieras y en segundo lugar, el bajo desarrollo de los mercados de capitales de los países en vía de desarrollo que no permite que las empresas tengan acceso a fuentes de financiamiento como el capital de riesgo. Las implicaciones de política de estos resultados son amplias, entre ellas, se encuentra la posible generación de mercados de capitales para pequeñas empresas en los países en vía de desarrollo y de la creación de subsidios a la tasa de interés para proyectos innovadores como un complemento de las políticas de subsidios indirectos mediante descuentos impositivos ya aplicados ampliamente a nivel internacional.

En tercer lugar, se encontró que los subsidios a la innovación en el largo plazo tienen efecto especialmente en las pequeñas empresas, mientras que en las grandes empresas dichos efectos son mínimos. Este resultado es novedoso porque abre la puerta para nuevas

políticas de subsidios gubernamentales basadas en las pequeñas empresas que son las que más sufren las problemáticas de financiación para proyectos innovadores. De igual forma se encuentra que mediante la política de generación de subsidios se puede fomentar el empleo de alto nivel en las compañías y que es una forma por tanto de evitar impedimentos de conocimiento en los proyectos de innovación. Otra de las novedades de esta investigación es que muestra cómo la generación de una política de subsidios recurrentes para las empresas puede generar mayores efectos en las compañías, especialmente las pequeñas. Esto a su vez, genera una propuesta de política para la implementación de programas de innovación de largo plazo dirigido a las pequeñas empresas en lugar de enfocarse en una metodología de "escoger el ganador" como se ha venido haciendo en el pasado especialmente en países como Colombia.

Acknowledgments

The idea behind pursuing a Ph.D. begun when I was working on CIDEI research center in Bogotá; for those days, I was dealing with projects in which my main goal was to prove firm owners that innovative ventures carried out in association with CIDEI were profitable, however, when I begin researching, found out that there was little theory about the subject. When I told my bosses about the idea of investigating the relationship between finance and innovation, they were delighted and gave me the corporate support needed to get a scholarship, thus, the first thanks I must give them to Myriam Pelaez and the late Vicente García.

Once enrolled in the Ph.D. I was encouraged and supported by many people, and I hope not to forget any of them, in first place to my advisors, Asunción Lopez and Juan Carlos Salazar Elena, who supported and pressed me enough to finish the thesis even though much of it was done far away in Colombia. During my Ph.D. time in Colombia there were some academic friends who support this research; Iván Hernandez Umaña, Florentino Malaver and Maricela Vargas contributed with readings of previous versions of this thesis, useful advices on its development and finally, access to my actual position of Corporate Finance Teacher at Pontificia Universidad Javeriana.

At the same time, a Ph.D. is a task that consumes a lot of time and resources, in my case, those resources were granted by COLCIENCIAS, so thanks to this institution. Since august 2016 I have been working in Universidad Militar Nueva Granada as a full-time researcher, and I want to thank all my colleagues in the economics and management faculty and in its research center for their valuable comments on some researches derived from this thesis.

Simultaneously, my Ph.D. time was an excellent moment to knew good friends in Spain like Alberto Santos, Gerardo Heredia, Gonçalo Mateus, Ignacio Massardo, Diego Camargo, Johana Ramirez, Esteban Sánchez, Gabriel Albornett, Ricardo Gómez, Emmanuel Díaz, Chloe Rosset, Jair Correa, Nicole Campos, Fran Medela and Patricia Vallejo, I'm sure that without you, it would have ended my thesis a year before, but I would not have had so much fun.

I want to thank to my long-time friends in Colombia also, they are Sayed Guarín, Sofia Rodriguez, Laura, Oscar and Omar Palacios, Carlos Forero, and Oscar Arturo Gonzalez, thanks for been my neighborhood family. To my college partners Alejandro Morales, Jorge Cuenca, Andres Ospitia and Rafael Ordoñez who give me great mental support during these years; to my godparents Daira Ordoñez and Levis Bernal who more than friends have become brothers in recent years. I also want to thank to my quasi co-workers in the Pontificia Universidad Javeriana, they are Sergio Cuellar and Claudia Mejía.

My family was a huge support also, so, thanks to my beautiful mother Elsa, my brothers Javier and Mario, my uncle Hernan Morales, my niece Laura and her mother Maritza, you guys were the main reason to pursue my Ph.D. I must give special thanks to my political family too, Luisa Maria Rodriguez and Humberto Moreno who have welcomed me as if I were his own son.

Last, but not least, I want to give thanks to my wife Norma, you are my favorite person in the world, and the real reason behind this thesis was ended; thanks for your supporting comments and your loving remainders, I hope we have a lot of time together for more adventures in the future.

Content

Chapter 1. General introduction 8

1.1. General data and methodology 15

1.2. Bibliography 18

Chapter 2. A dynamic approach to the role of innovation barriers: a longitudinal analysis for Spanish manufacturing SMEs 20

2.1. Introduction 20

2.2. Literature review 23

2.2.1. Perception of barriers and innovation performance 23

2.2.2. Barriers through the different stages of the innovation process 24

2.3. Data and methodology 26

2.3.1. Data 26

2.3.2. Methodology 27

2.4. Results 29

2.4.1. Invention phase: failure 29

2.4.2. Invention phase: invention success 29

2.4.3. Appropriation phase: failure 30

2.4.4. Appropriation phase: success 31

2.5. Discussion and concluding remarks 32

2.6. Bibliography 35

Chapter 3. Show me the money: pecking order and funding sources for innovative firms in Colombia 38

3.1. Introduction 38

3.2. Literature Review 40

3.3. Data, methodology and expected results 47

3.4. Results 51

3.4.1. Results from the full sample 51
3.4.2. Sub-sample results 54
3.5. Conclusions 59
3.6. Bibliography 62
Chapter 4. Where did the money go? Long-term input and output additionality of innovation subsidies in Spain 67
4.1. Introduction 67
4.2. Literature review 69
4.2.1. Issues with policy evaluation methodologies 69
4.2.2. Evaluation of innovation subsidy policies in practice 73
4.3. Empirical Approach 76
4.3.1. Methodology 76
4.3.2. Data 78
4.4. Results 81
4.4.1. Effects on SMEs and large firms 83
4.4.2. Single vs. recurrent subsidies 84
4.5. Conclusions 86
4.6. Bibliography 88
Chapter 5. Concluding remarks and policy implications 94
5.1. Complete bibliography 101

Chapter 1. General introduction

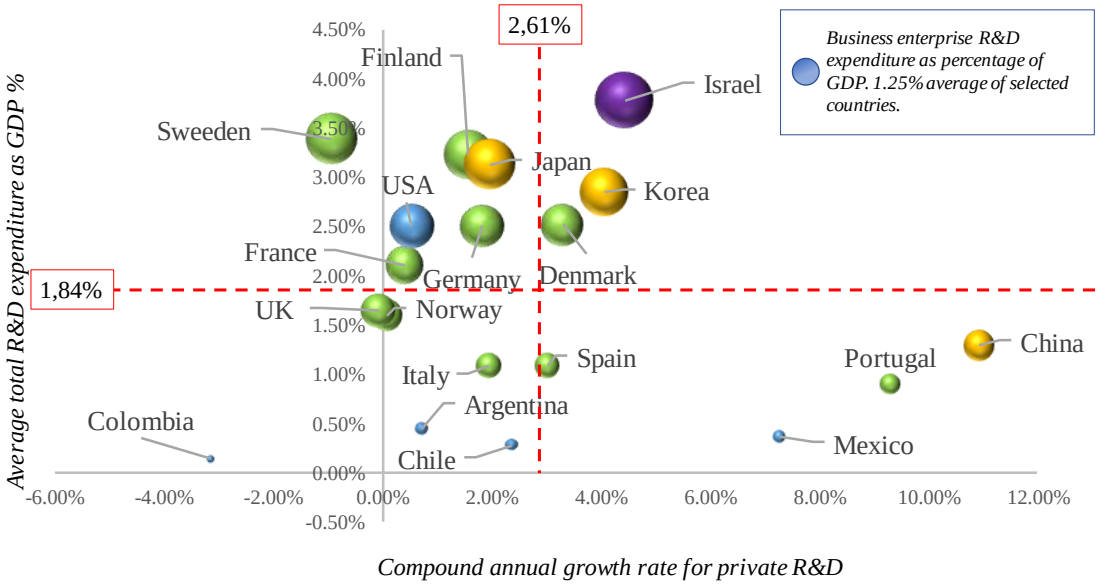
Since its foundation, economic science has been concerned about the optimal strategies needed to generate economic growth within regions and nations. The neo-Schumpeterian approach based on markets' evolutionary characteristics has created a still heterodox (although not new) explanation of economic growth created by the engine of innovation within firms.

Thus, economic growth is created by firms, whose main objective is to elevate their profits developing new ways of generating production outputs and processes linked to that production (Nelson, 1959; Nelson & Winter, 1982; Verspagen, 2005). As regards evolutionary economics literature, the mechanism linking economic growth and innovation is productivity (Nelson, 1959). Accordingly, Griliches (1988) showed that Research and Development (R&D) expenditures elevate countries' productivity, and therefore, it has an important impact on long-term growth in world economies; he presented evidence of a relationship between diminishing labor productivity in the 1970s and a simultaneous sharp reduction in R&D expenditures in the US. Similarly, Brown et al. (2009) shows that there is a connection between private R&D investments and economic growth and suggests that the 1990s boom of R&D investments contributed to labor productivity growth in the U.S. economy.

Given this evidence, it would be thought that investments in R&D should be an extended process in all regions of the world, especially in those less developed, since this type of investment would allow them to generate growth that leads to matching the developed economies. However, there are still important differences on R&D expenditures between countries. Trying to overcome those differences, governments around the world have established innovation policies to elevate the R&D expenditures rate in past years, an example of that is the Horizon 2020 strategy developed by the European Union (EU), in which one of the main goals is to elevate the rate of R&D expenditure to 3% of EU gross domestic product (GDP); another example is the Colombian government strategy to elevate R&D expenditure to 1% of its GDP (De Sabios, 1996). However, to date, these figures have not been reached.

In Figure 1, a selection of nineteen countries is showed. The abscissa axis shows the compound annual growth of private R&D business (1996-2014), the ordinate axis shows the average total R&D as a percentage of GDP (1996-2014) and the dimension of the bubbles shows the average private business total R&D as a percentage of GDP (1996-2014). There are big differences among countries; for instance, most North European countries, Israel, Japan, Korea, and the U.S. have higher than average total expenditures on R&D (1.84%) Moreover, Mexico, Portugal, China, Spain, Denmark, and Korea are growing their private business R&D expenditures at a higher speed than the average of selected countries (2.61%). Some economies like Chile, Argentina, Colombia, and Italy, have lower averages of total and private R&D expenditures and have lower growth speed. The case of Colombia is worth mentioning; it has a lower average of total and private R&D expenditure and a negative annual growth rate of 3.15%. At this speed, the R&D structural differences of countries like Colombia, Chile, Argentina, and Italy against more developed countries like Israel, Korea, and others will increase in the long-term.

Figure 1. Total R&D expenditure of selected countries (1996-2014)

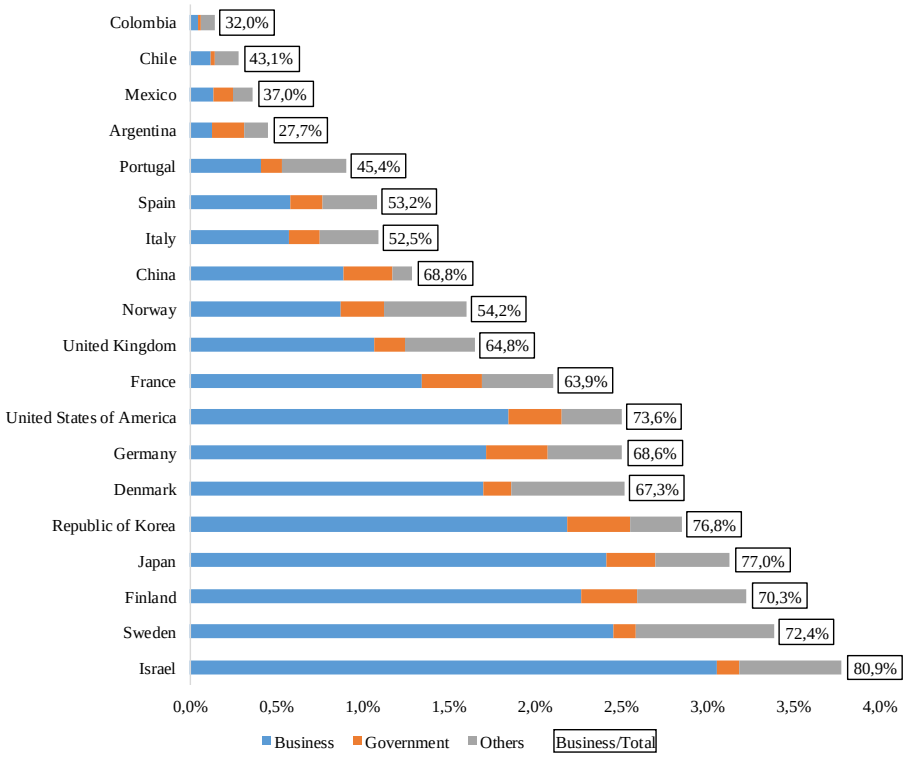


Source: UNESCO. Chile (2007-2014), Mexico (1996-2011), Norway (1997-2014), Sweden (1997-2014), and the USA (1996-2013)

The fact that Latin American countries (Colombia, Chile, Argentina and Mexico) show lower R&D expenditures and paces, while in some countries like Israel, Korea, or Denmark, these figures are high, leads one examine the causes of such differences between countries. At first sight, the bubbles dimension in Figure 1 gives some clues

about a critical R&D phenomenon (i.e., the amount of private R&D expenditures in each country). Countries with the lowest expenditures in R&D like Colombia, Chile, Argentina, and Mexico have lower private business expenditures on R&D. In Figure 2, a comparison of the expenditures of R&D by those selected countries is shown. In countries like Colombia, Chile, Mexico, or Argentina, private business participation in the total R&D expenditure is minimal, with Colombia having the lowest level of all selected countries with 32% of total R&D expenditure. Additionally, countries in which the total R&D expenditure is above average present higher levels of private participation within R&D expenditures; countries like Korea, Japan, Finland, Sweden, or Israel, display levels higher than 70% of total R&D expenses.

Figure 2. Total R&D by sector of performance (1996-2014)



Source: UNESCO. Chile (2007-2014), Mexico (1996-2011), Norway (1997-2014), Sweden (1997-2014), and the USA (1996-2013). Others include non-profit organizations and universities.

In this sense, it is possible to argue that the amounts of private R&D expenditures are related to the low total R&D expenditures at the national level. We do not yet fully understand the reasons behind those low levels of private R&D investment, or the differences between countries. However, the literature in the last century have been focused on some plausible explanations for this issue.

First, there are factors hampering private business expenditure on innovative activities. This issue has been researched since the seminal works of Nelson (1959) and Arrow (1962); in general, private investment in innovation is highly risky from the financial point of view, mostly because it requires high levels of cash flow, is a costly long-term venture, is highly uncertain, and sometimes produces outcomes that are intangible. Those factors are caused by market failures like information asymmetry and the impossibility of full outcomes appropriation; those market failures elevate the risk and costs of innovation ventures relative to investments based on traditional capital assets (Hall & Lerner, 2010).

Thus, firms trying to implement innovation activities face strong impediments trying to raise money from internal and external sources. First, internal funds are scarce and sometimes available cash flow has to be used to cover other types of expenditures, especially if a company is cash restrained, as is the typical case in young and small firms (Hall & Lerner, 2010). In addition, innovative firms trying to raise money from external sources face high financial direct and sunk costs given the intangible nature of innovation and its uncertainty characteristics. Therefore, all those factors shaping the way innovative firms finance their Research, Development and Innovation (R&D&I) expenditures should be understood to generate optimal policies to elevate firms' expenditure on R&D, especially for firms, regions, and countries with low innovation activities like the ones posted in Figure 1. In recent years, the study of those failures has been favored by the researches of impediments to innovation using innovation surveys.

Second, some academics have proposed that differences in innovative inputs within countries, like the ones shown in Figure 1 and Figure 2, may be due to the different organizational and institutional mixtures and relationships present in innovative markets across countries. For economies in which the private investment in R&D is low, it is consistent to think that the development of strong organizations backing up innovation is necessary, in that sense, one of the main functions of those organizations and institutions is to ease the way in which firms and more generally, the market, perceive and face impediments to innovation. This academic approach began with the seminal work of Freeman (1987), Lundvall (1992), and Nelson (1993); for Freeman, these relations are framed in what is known as the National Systems of Innovation (NSI), that

he defined as “the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.”

In the same way, Edquist (2010), proposes that one of the fundamental activities of NSIs is the financing of private innovation activities facilitating commercialization and adoption of technologies; for countries with low amounts of private R&D expenditures, it is possible that some of the institutional and organizational framework already developed in countries like Israel, Korea, and other countries are not yet fully developed.

In that sense, researchers have tried to uncover the complexities of the relationship among impediments, finance, and the institutional framework of innovation, trying to understand the causes behind the differences in R&D expenditures around the world. In that respect, since Schumpeter it has been argued that the relationship between innovation and its financial arrangement is fundamental to understand economic cycles and development:

> The logical relation (…), between what is called “credit creation by banks” and innovation, will not be lost again. This relationship, which is fundamental to the understanding of the capitalist engine, is at the bottom of all the problems of money and credit, at least as far as they are not simply problems of public finance (Schumpeter, 1939, p. 111).

In addition, Schumpeter understood that there are some issues with the relationship between financial markets and innovation created by information asymmetries, and that these failures make financial market organizations misread the innovation phenomenon:

> …the failure of the banking community to function in the way required by the structure of the capitalist machine accounts for most of the events which the majority of observers would call “Catastrophes.” It is but natural that since such failure primarily shows in dealing with novel propositions —where judgment is most difficult and temptation strongest—an association has developed between financing innovation and miscarriage or misconduct which, however

understandable, does not make analysis any easier (Schumpeter, 1939, pp. 117-118).

However, even though a great number of efforts have been made in the last century to understand innovation impediments, financial arrangement, and innovation framework, and even now that microdata is available to research this issue, it is still difficult for firms, academia, and policy makers to understand financing innovation phenomenon deeply. Therefore, firms still face market failures impeding private R&D expenditure and decelerating the pace of productivity, and countries around the world still need to complete the introduction of an institutional framework in order to back up private innovation funding, especially in underdeveloped economies.

Literature about the finance of innovation has made it known that young, small, and medium sized and high technology innovative firms tend to confront innovation impediments in higher proportions than their counterparts; additionally, financial markets' evolution supports the creation of instruments like venture capital, and institutions like small firms' exchange markets to overcome impediments of innovative and high growth firms. However, those instruments and institutions are highly specialized and not available to all companies, especially in emerging markets in which the number of venture capital firms or angel investments and investors are minimal. In that sense, the Edquist (2010) approach to NSI is relevant (i.e. it is necessary to create and develop financial instruments and institutions backing up innovative ventures).

Nevertheless, the literature has uncovered some clues about how big, publicly traded firms finance their innovation ventures, but we still do not fully understand how market failures shape the capital structure of smaller, private innovative firms. Likewise, for firms confronting strong innovation impediments, governments around the world have developed financing instruments like subsidies with the aim of increasing innovation activity and generating positive knowledge spillovers on markets. However, we still do not fully understand the effects of those instruments in the long-term innovative behavior of firms.

Many additional questions remain unanswered in the financing-innovation framework. This dissertation is a small effort to increase knowledge about this phenomenon using

microdata for firms located in Spain and Colombia; in general, the dissertation focuses on a broad research question: what are the financing sources and innovative particularities of small innovative firms facing innovation impediments?
Further, this dissertation tries to answer some specific research questions that will be answered in each of the following chapters:

Chapter 2:

- In what phase of innovation process do small firms tend to perceive financial, knowledge, and market impediments related to the innovation phenomenon?
- Which impediments are perceived by firms already profiting from innovation?

Chapter 3:

- What are the main characteristics of firms' founding innovation activities through internal, banking, equity, and public sources of funds?
- How can the capital structure of firms performing innovation activities in an underdeveloped country like Colombia be characterized?

Chapter 4:

- What are the long-term impacts of innovation subsidies granted by governments on input and output variables of firms?
- What is the long-term effect of recurrence on innovation subsidies in the innovative performance of companies?

Providing answers to these questions is fundamental from the policy point of view, since it will allow the development of better intervention measures, organizations, and institutions, so that companies can overcome innovation impediments, finance innovation projects more efficiently, and, in turn, generate knowledge, innovative products and processes more efficiently and in the long-term, generate economic growth. Specifically, this thesis deals with the effect of innovation impediments, financing innovation, and public subsidies on small and medium-sized firms versus bigger companies, because the latter tend to perceive market failures in higher degrees (Hall & Lerner, 2010).

1.1.General data and methodology

Collecting data about the innovation activity and financial behavioral of innovative firms is not an easy task, and collecting comparable data about these topics is even harder. However, beginning in the early 1990s some countries have performed the titanic labor of gathering data about innovation activities at the firm level in order to generate better indicators than the typical ones used in the 1970s and 1980s. In that sense, in 1992 the Organization for Economic Co-operation and Development (OECD) issued the Oslo Manual; this document was developed for two main goals, providing guidelines to create, measure, and compare innovation indicators within OECD country members, and discussing the analytical problems to which those indicators are relevant (OECD, 1997).

Following the guidelines of the Oslo Manual, the EU developed the Community Innovation Survey (CIS) as a large-scale attempt to compare inputs and outputs of innovation activities of firms around the EU (Arundel & Smith, 2013), and since the year 2004 the survey has been applied every two years. A special case of the CIS is the "*Panel de innovación tecnológica*" (PITEC). Developed by Spanish government, this survey is developed on a yearly basis and is accessible freely. For the purpose of this dissertation, the PITEC data base was used in Chapter 2 (2003-2013) in an attempt to measure the perception of innovation impediments of Small and Medium-sized enterprises (SMEs), and in chapter 4 (2007-2013) to measure the impact of government subsidies on the innovation activity of Spanish firms.

Following the EU survey activities, some other regions of the world have developed their own surveys based on the criteria of the Oslo Manual, especially in Latin America (Salazar & Holbrook, 2004). In that sense, special attention needs to be paid to the exercises carried in countries like Mexico, Chile, Argentina, Uruguay, Ecuador, or Colombia. For Colombia, two surveys have been developed, the first for manufacture industries (EDIT-Encuesta de innovación tecnológica) and the second for services and commerce (EDITS-Encuesta de innovación Tecnológica en Sectores de Servicios y Comercio) industries. These surveys have been carried on since 2005 and 2006, respectively; for this dissertation, the 2007-2009 EDIT was used to determine the funding sources that Colombian innovative firms use to finance their innovation ventures.

The methodologies used for this dissertation were panel probit models, multivariate probit models, and conditional difference in differences (CDID); each of these methodologies was used in order to overcome some specific issues or advantages of the data. In addition, some limitations of this thesis arise from the data and methodologies chosen. In the first place, in the case of Colombia, only one wave of the EDIT survey was available even when there were multiple waves of this survey; the limited access to safe repositories in Bogota´s national statistical office (DANE) and restrictions about the international transference of data did not allow access to other waves of the survey. Moreover, this survey does not allow access to output variables such as company revenues that would have been valuable to cross-refer information about financial behavior and output variables of firms. Likewise, in the case of the long-term effect of public subsidies on Spanish firms, the CDID methodology uses a linear approximation to measure the innovative performance of firms. In this regard, behavioral variables like cooperation, innovation, and patent propensity are measured by the PITEC as binary or count variables; therefore, it was not possible to verify if there were effects on the long-term innovative behavior variables of firms.

The thesis is organized as follows. In the second chapter, research about the perception of innovation impediments of SME manufacture firms in Spain for the years 2005-2013 is presented. This chapter tries to uncover the way that innovation impediments act on firms during the innovation process with a dynamic approach; in that sense, special attention is paid to the different forms of market failures through firms' perceptions of impediments to innovation from the beginning until the end of the process. Chapter 3 presents research dealing with the funding sources and capital structure of innovative firms in Colombia; specifically, this chapter deals with the effects of market failures on access to specific funding sources like cash flow, banks, equity, and government subsidies in a country with underdeveloped financial markets and with the structure of capital markets in underdeveloped countries. In Chapter 4, and given that firms facing strong market failures tend to have low expenditures on innovation, research on the long-term effects that government subsidies have on Spanish firms was carried out. In this chapter, special attention is paid to the difference of the effects of those subsidies on input and output innovation variables and to the firm size as a fundamental variable to

determine those effects. Finally, in Chapter 5 the general conclusions of the thesis, the policy impacts, and a proposal for a future research agenda are presented.

The functional form given to this dissertation, separated into three chapters with different but related objectives, has as its objective the short-term submitting of these chapters to peer-reviewed journals once the thesis is approved. Additionally, even though in this thesis my role was as a principal investigator, the coauthors of Chapters 2 and 4 are Juan Carlos Salazar and Asunción López from Universidad Autónoma de Madrid, and I want to give credit to them. For Chapter 3, I received valuable contributions from Florentino Malaver and Maricela Vargas from Pontificia Universidad Javeriana, especially in factors related to data collection. Notwithstanding the great support I have received from all of them, the responsibility for any errors or omissions remains my own.

1.2.Bibliography

Arrow, K., 1962. Economic welfare and the allocation of resources for invention. In: T. R. Corporation, ed. In *The rate and direction of inventive activity: Economic and social factors*. Boston: Princeton University Press, pp. 606-626.

Arundel, A. & Smith, K., 2013. History of the community innovation survey. In: F. Gault, ed. *Handbook of Innovation Indicators and Measurement*. s.l.:Edward Elgar Publishing, pp. 60-87.

Brown, J. R., Fazzari, S. M. & Petersen, B. C., 2009. Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom. *The Journal of Finance,* 64(1), pp. 151-185.

De Sabios, I., 1996. Informe de la misión de sabios. Colombia: al filo de la oportunidad, Bogotá: Tercer Mundo Editores.

Edquist, C. 2010. Systems of innovation perspectives and challenges. *African Journal of Science, Technology, Innovation and Development*, 2(3), 14-45.

Freeman, C. 1987. *Technology policy and economic performance: Lessons from Japan*, London: Pinter.

Griliches, Z., 1988. Productivity Puzzles and R & D: Another Nonexplanation. *The Journal of Economic Perspectives,* 2(4), pp. 9-21.

Hall, B. H. & Lerner, J., 2010. The financing of R&D and innovation. In: *Handbook of the Economics of Innovation*. s.l.:s.n., pp. 609-639.

Lundvall, B. 1992. *National systems of innovation: Towards a theory of innovation and interactive learning*, London: Pinter.

Nelson, R., 1959. The simple economics of basic scientific research. *Journal of political economy*, 67(3), pp. 297-306.

Nelson, R. R. & Winter, S. G., 1982. *An evolutionary theory of economic change*. Harvard Business School Press.

Nelson, R. R. 1993. *National systems of innovation: A comparative study*, Oxford: Oxford University Press.

OECD, 1997. The measurement of scientific and technological activities: proposed guidelines for collecting and interpreting technological innovation data: Oslo manual. 1 ed. Oslo: Organization for Economic Co-operation and Development.

Salazar, M. & Holbrook, A., 2004. A debate on innovation surveys. Science and public policy, 31(4), p. 254.

Schumpeter, J. A., 1939. Business Cycles: *a theorical, historical, and statistical analysis of the capitalist process*. 1 ed. New York (New York State): Harper and Brothers.

Verspagen, B., 2005. Innovation and Economic Growth. In: J. Fagerberg, D. Mowery & R. Nelson, eds. *The Oxford handbook of innovation*. New York: Oxford University Press, pp. 487-513.

Chapter 2. A dynamic approach to the role of innovation barriers: a longitudinal analysis for Spanish manufacturing SMEs

2.1.Introduction

In his much-celebrated article, Teece (1986) attempted to explain why innovating firms often fail to obtain significant economic returns from innovation. He highlighted the fact that, in order to produce a successful innovation, it is not only necessary to generate the "core knowledge" embedded in a new product but also the capabilities to appropriate the benefits of the new product (or at least part of them) in markets. In this sense, a successful innovation requires not only an invention plan but also an appropriation plan involving the management of production and commercialization of new products. Or, equivalently, firms' success in the "invention" stage of innovation process does not imply success in the "appropriation" (or commercialization) stage.

Although this approach explicitly tackles the analysis of barriers faced by innovative firms in the production and commercialization phase (i.e., the appropriation stage, after the generation of the invention), empirical research relating firm's perception of barriers to innovation and its corresponding innovation performance has overlooked the contribution of Teece in the analysis. Using firm-level panel data from the Community Innovation Survey (CIS, Spain), we show that the convergence of these two lines of research allows us to obtain consistent and intuitive empirical results through firm-level analysis, by assigning each type of barrier to a specific stage of the innovation process.

Our approach and results also contribute to the discussion that has taken place in specialized literature regarding to the counterintuitive results obtained in some empirical research using microdata (i.e., that the propensity to innovate is positively related with perceived barriers to innovation). Several interpretations of this result have been provided. Baldwin & Lin (2002) argue that innovation is a learning process in which innovators daily face problems that need to be solved, but firms with no innovation activities simply do not have to confront those impediments and therefore they do not

perceive them. Mohnen et al. (2008) conclude that innovative firms are prone to perceive barriers because both phenomena—innovation and barriers—are determined by the same factors, i.e., firms perceiving barriers are those actively involved in innovation activities. Savignac (2008), working with economic/financial barriers, argues that this unexpected result is due to a selection bias of their sample, in which firms not willing to innovate, and therefore not perceiving barriers, are also asked about impediments to innovation, concluding that there is a positive relationship between innovation results and barriers. In the same direction D'Este et al. (2012) argue that there are revealed barriers for innovative firms, i.e., barriers perceived by firms within the innovation process, and deterrent barriers, i.e., barriers discouraging firms from starting innovative activities. Therefore, if we want to capture these effects, it is necessary to select only firms "interested" in innovation activities. Aligned with this recommendation, Blanchard et al. (2013) analyzed the impact of perceived barriers on innovation performance, focusing only on those firms actively trying to innovate, concluding that barriers are inversely related with innovation propensity.

Although specialized empirical research on this area (using CIS-type surveys) has mainly focused on economic/financial barriers, other studies have analyzed the impact of different types of nonfinancial barriers, including "market barriers." In those cases, market barriers are related to performance in the invention stage (i.e., the creation of a new product) and not in the commercialization stage. As we will see in our research, these market barriers are considered, according to our nomenclature, as barriers perceived in the commercialization stage. Our results will show that a proper selection of a variable of performance in this last stage of the innovation process provides consistent results regarding the relation between market barriers and innovation performance.

In this researc, we extend these previous ideas, introducing the analysis of diverse types of barriers (cost-funding, knowledge, and market) in different stages of the innovation process (i.e., the invention or appropriation stage). We show not only that barriers have significant impact on firms' propensity to innovate (as in Blanchard et al., 2013) but also that the perception of knowledge barriers is typical for firms "failing" in the invention stage; that economic/financial barriers are typical also in the invention stage regardless of the outcome of this stage (failure or success); that market barriers are

typical among firms "failing" in the appropriation stage; and, finally, that success in both stages of the innovation process is characterized by the perception of no barriers. With our approach, therefore, we contribute to the understanding and explanation of counterintuitive results, that barriers exhibit a direct relationship to the propensity to innovate. In this research, our results show that each stage of the innovation process is influenced by different type of barriers, and also, that the perception of barriers has an intuitive explanation regarding the sign of the effect for each analysis stage.

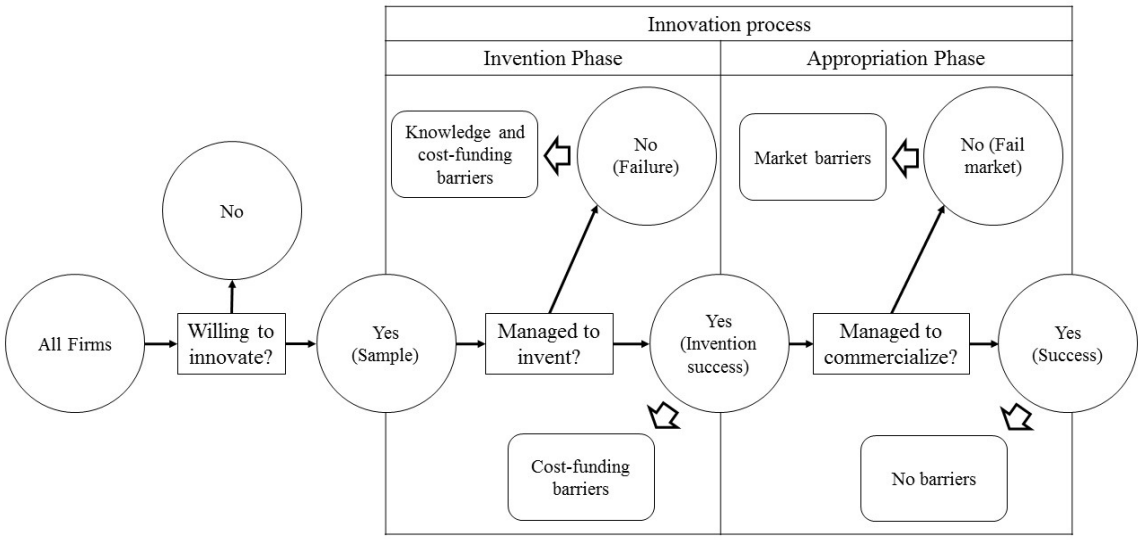
The data set used is a sample of 3,256 manufacturing Small and Medium Enterprises (SMEs) during the period 2005-2013, included in the Technological Innovation Panel (PITEC, per its acronym in Spanish), which is a panel constructed with the information from the Community Innovation Survey for Spain (CIS-Spain). The general idea of the empirical research of our study is to analyze the propensity either to fail or succeed in each of two stages of innovation process: invention and commercialization. This approach leads us to four models (two for each stage). All models were estimated using probit regressions with panel data techniques.

As explained before, many studies found a counterintuitive positive relation between perceived barriers and innovation performance. Pellegrino and Savona (2013) suggested that there are some problems with data that might cause these types of results. The first one is the presence of unobserved firms' specific factors. The second is a specific source of bias that is linked to an inappropriate selection of the relevant sample for the analysis. To overcome the first problem, we used panel data techniques to capture unobserved heterogeneity among firms. The second problem was tackled by selecting a sample of firms "willing to innovate," as proposed by Savignac (2008), D'Este et al. (2012), and Blanchard et al. (2013).

A brief summary of the procedure and results is presented in Figure 3. This figure was adapted from Pellegrino and Savona (2013) to include the commercialization stage of the innovation process. It can be seen that we restricted our analysis to those firms willing to innovate, (1) using firms with positive expenditures on Research, development and innovation (R&D&I) at least once during 2005-2013 and (2) eliminating firms declaring that they were not interested in innovation. Our results show that the perception of economic/financial barriers was typical in the invention stage,

regardless of the outcome of the stage (failure or success). On the other hand, knowledge barriers provided an explanation for "failure" in this initial stage of the innovation process, meaning that succeeding at this stage implied overcoming such knowledge constraints. During the commercialization stage of the innovation process, "failure" was characterized by the perception of *market barriers*, while "success" could be explained as a situation of perceiving no barriers.

Figure 3. Research procedure and main results



Source: Authors, adapted from Pellegrino and Savona (2013)

The chapter is organized as follows. In Section 2.2, we review the specialized literature analyzing the relationship between perceived barriers and innovation performance, with specific emphasis on empirical analysis based on the use of CIS-type microdata. We expand the approach of this literature with the introduction of Teece's framework in Section 2.2.2. In Section 2.3, the data and methodology are discussed. Results are presented in Section 2.4, and Section 2.5 provides some concluding remarks.

2.2.Literature review

2.2.1. Perception of barriers and innovation performance

Seminal works by Arundel (1997), Mohnen & Rosa (2001), Baldwin & Lin (2002), and Canepa & Stoneman (2002) opened a path of research about innovation barriers' perception and their effects on firms' innovation activity. This path has been followed by several authors, especially based on European data using the CIS, which contains specific questions about the factors hampering innovation activities in firms.

Much of this literature (Tourigny & Le, 2004; Silva et al., 2008; Segarra-Blasco et al., 2008; Madrid-Guijarro et al., 2009; Blanchard et al., 2013; Pellegrino & Savona, 2013) seeks to determine the relationship between innovation barriers and firms' propensity to innovate; generally, this literature concludes that economic/financial and knowledge barriers are the most relevant factors deterring firms' innovation; equally, this literature shows that there are some firm characteristics, such as size, age, innovation intensity, corporate composition, and location, that determine firms' perception of barriers (Iammarino et al., 2007). Although this literature has made important contributions to understand how barriers affects firms, the whole process of innovation cannot be measured only until the moment a firm develops their products or services, because if the firm cannot take its innovations into the market and generate revenues from them, it is not achieving the proposed objectives of innovation, i.e., the literature does not distinguish among barriers perceived during the invention and commercialization processes.

2.2.2. Barriers through the different stages of the innovation process

At the same time, there is a literature arm seeking to determine how innovation barriers affect firms in different stages of the innovation process, i.e., before innovation projects start or while firms are developing an idea into a product or process. Canepa & Stoneman's (2002) study, which, as we know, was the first of this type, sought to prove how economic/financial barriers determined the likelihood of not starting, delaying, or abandoning an innovation project in different European countries; they found that economic/financial barriers are important impediments for firms wanting to start an innovation project but are not important when firms abandon initiated projects. In a similar vein, Galia & Legros (2004) found that the likelihood of postponing an innovation project rises when firms have a high perception of economic/financial barriers, but the likelihood of abandoning a started project increases when perceptions of market and knowledge barriers rise. Similarly, Savignac (2008) investigated if French firms engage in innovation activities when they perceive barriers to innovation, and found that the likelihood of realizing such activities is negatively related to economic/financial barriers.

As Galia & Legros (2004) Mohnen et al. (2008) found that economic/financial barriers perceived by Dutch firms decreased the likelihood of starting an innovation project and

were positively related to the likelihood of delay or prematurely stopping those projects. Similarly, they found that firms used to abandon their projects because of market and knowledge barriers, but to a lesser extent against the economic/financial barriers. They found also that the perception of economic/financial barriers reinforces the perception of market and knowledge barriers. Likewise, García-Vega & López (2010) found that Spanish firms tend to suffer market barriers in higher proportions, but economic/financial barriers are responsible for the abandonment of projects.

D'Este et al. (2012) and Blanchard et al. (2013) show that innovation barriers have dissimilar impacts if firms are involved in different stages of the innovation process; in that sense, there are deterring barriers that prevent firms from engaging in innovation activities, while there are revealed barriers that firms perceive when they are actively involved in innovation. According to these studies, it is important to separate firms involved in innovation activities from those willing to innovate but not habituated to the process, because the perception of barriers by these firms will be dissimilar.

Even when this branch of literature has tried to deliver a broader view of the innovation process and its relationship to barriers to innovation, it has failed to integrate a holistic vision of the innovation process, because it does not link other stages to it. A firm can be affected by different types of barriers in the conception or in the production stages and even can overcome them; however, this does not guarantee that firms can directly benefit from its innovations, because if the firm cannot sell its goods, innovation is not complete. So, if the marketing phase of innovation is also affected by specific barriers, firms will be in jeopardy when they are not allowed to overcome those impediments.

The fact that the market phase has been neglected in economic analyses was pointed out by Teece (1986), who highlighted the fact that in order to produce a successful innovation, it is not only necessary to generate the "core knowledge" embedded in the new product but also that the firm has to appropriate the benefits (or at least part of them) from its innovation activities. In this sense, a successful innovation requires not only an invention plan but also an appropriation plan involving the management of production and commercialization capabilities. This line of research has produced significant advances in providing a more comprehensive approach to innovation management (Hurmelinna-Laukkanen & Puumalainen, 2007; Castellacci, 2008; Pérez-

Cano, 2013; Henttonen et al., 2015); however, this line of research has been disconnected from the analysis of barriers to innovation. This is one of the contributions of this research; we argue that in order to understand the effects of barriers to innovation, it is necessary to include a holistic view of the innovation process. In this context, the hypothesis we are seeking to prove is that (H1) innovation barriers can affect appropriation (commercialization) phases of the innovation process as well, and that (H2) successful firms, i.e., firms taking inovative goods into the market, are those that can find the best way to overcome innovation barriers.

2.3.Data and methodology

2.3.1. Data

Data used for this research come from the Spanish Technologic Innovation Panel (PITEC, according to its acronym in Spanish). This database summarizes the responses of Spanish companies in the CIS between 2003 and 2013. The survey is conducted annually and contains panel data for companies in the manufacturing and service sectors.

Specifically, we used manufacturing companies with more than 10 and fewer than 250 employees who responded to the survey between 2005 and 2013. We used this sample because, as reported in literature reviews, small and medium-size firms report being affected by innovation barriers in higher proportions. In order to control for firms not interested in innovation activities, we included only firms that made expenditures on R&D&I at least once between 2005 and 2013. Similarly, firms answering that they were not interested in innovation activities were excluded from the sample in the year of that response, that is, a firm could be excluded in one year if in that particular moment in time they answered that they did not want to conduct innovation activities, but the same firm could be included in other years if they did not answer that question positively.

In line with our literature review, we were interested in determining in which part of the innovation process firms were more likely to experience innovation barriers. In Table 1 one can see that firms in the sample were more likely to fail taking inventions to market (28%) than in their development of inventions (5%). A significant number of firms (80%) were able to develop inventions, but a smaller number of those firms (70%) were

capable of selling their inventions in the market. With regard to innovation barriers, firms seemed to report more frequently that economic/financial barriers affected them in a strong way (51%), and a strong effect of market barriers (33%) seemed to be more frequent than knowledge barriers (24%).

Table 1. Variable summary statistics

	Full survey			***Sample***		
	Mean	***Std. Dev.***	***N***	***Mean***	***Std. Dev.***	***N***
failure	0.04	0.20	12,620	0.05	0.21	3,278
fail_market	0.20	0.40	12,754	0.28	0.45	3,282
invention	0.69	0.46	12,839	0.80	0.40	3,282
succes	0.56	0.50	12,755	0.70	0.46	3,282
eco_fin_barr	0.47	0.50	12,620	0.51	0.50	3,278
know_barr	0.22	0.41	12,620	0.24	0.43	3,278
market_barr	0.29	0.45	12,620	0.33	0.47	3,278
size (log)	4.20	1.66	12,755	3.90	0.88	3,282
inn_exp (log)	4.88	4.23	12,755	6.24	3.63	3,282
pub_funds	0.30	0.46	12,620	0.36	0.48	3,278
group	0.40	0.49	12,749	0.34	0.47	3,282
pat	0.11	0.31	12,754	0.14	0.35	3,282
htec	0.03	0.17	12,839	0.08	0.27	3,282
mhtec	0.12,	0.33	12,839	0.37	0.48	3,282

2.3.2. Methodology

In order to determine the way that innovation barriers affect the process of innovation, a panel data probit model for PITECs between 2005 and 2013 was performed. Following the Teece (1986) aproach, we divided the innovation process in two phases: (i) the invention phase, from the conception of the innovation project to its crystallization in a new product or process; and (ii) the appropriation phase, where the firm designs a strategy to profit from its innovative activities in the market.

We were interested in determining which effects innovation barriers had on firms' likelihood of failing or succeeding in the invention and appropriation phases; following that notion, the empirical research consisted of four models divided into failure and success in the invention and appropriation phases. All models had the same set of independent variables and the same sample; we used the random-effects probit regression, because the estimators for the fixed-effects technique could be biased.

In order to define if a firm failed in the invention phase (failure) we use a binary variable in which 1 represented firms that abandoned projects in the conception phase, firms that abandoned started innovation projects, or firms without innovation outcomes.

For success in the invention phase (invention_success), we used a binary variable with 1 representing a firm that developed product or process innovations. Failure in the appropriation binary variable (fail_market) was 1 when a company with a product or process innovation had no revenues for innovation. Finally, for success in the appropriation phase (success), we considered a binary variable equal to 1 for firms with revenues related to innovation. Given that we have a panel data set, firms could have been in a subset in one year but change category in the next one, e.g., a firm could fail in the invention process in one year and succeed in the appropriation phase a few years later; therefore, we considered the evolutionary nature of the innovation process inside firms.

The model used to determine the relationship between innovation barriers and innovation outcomes grouped barriers into three different categories defined by PITEC; the economic/financial category included (I) lack of funds for the firm or group of firms, (II) lack of external financial funds, and (III) innovation is too expensive. Knowledge barriers included (IV) lack of qualified personnel, (V) lack of information about technology, (VI) lack of information about markets, and (VII) difficulties finding cooperative partners. Finally, market barriers included (VIII) market dominated by established enterprises and (IX) uncertainty regarding market demand for innovative goods and services. For each of the three categories, we included a dummy variable with a value of 1 if a firm had a strong perception of any of the barriers composing each category.

The model also includes control variables like the log of the number of employees, log of the innovation expenditure by employee (inn_exp), a dummy variable equal to 1 if the company cooperated with other firms in that particular period (coopera), a variable equal to 1 if the company received public funds for R&D and innovation activities (pub_funds), and a dummy variable equal 1 if the firms was part of a business group (group). We also included a dummy variable equal to 1 if the firm had any patent applications (pat), a variable equal to 1 if the firm was in high technology sectors (htec), and a dummy variable for firms in medium high technology sectors (mhtec). Finally, we considered the effect of time, including a set of year dummies. So, the model to verify the relationship between innovation barriers and results was as follows:

$$R_{i,j,t} = I[\beta' Z_{j,t} + \delta' Y_{j,t} + c_t + \varepsilon_{j,t} > 0]$$

where $R_{i,j,t}$ represents each one of the types of failure and success defined above (Table 1), $Z_{j,t}$ is the control variable vector, $Y_{j,t}$ represents the three groups of innovation barriers, c_t is the unobserved invariant time effects, and $\varepsilon_{j,t}$ is the idiosyncratic error term; the models were estimated using a panel probit methodology with random effects.

2.4.Results

In order to facilitate the interpretation of the results in Table 2, we are going to analyze the results for each one of the models in separate ways.

2.4.1. Invention phase: failure

Sometimes, it is possible that companies, despite making innovation expenditures, fail in their attempts to develop new products and processes; our probit model shows that smaller firms are likeliest to fail in the invention phase, while companies with lower investments in innovation activities and firms belonging to an industrial group fail in larger proportions. Cooperation seems to diminish the likelihood of failing, and high and medium high technology firms are more prone to fail in the invention phase.

As barriers to innovation refers, economic/financial and knowledge barriers have influence in the failure on invention phase. It seems that funding, costs, manpower, cooperation and information are fundamental factors at the beginning of the process. These results are aligned with those described in the review of the literature section.

2.4.2. Invention phase: invention success

The results of the probit model show that the largest SMEs are likely to succeed in the invention phase; likewise, firms with the highest innovation expenditures, cooperation agreements, and patent applications are more likely to be successful inventors. Surprisingly, the fact that a firm belongs to a high or medium high technology sector is not related to its propensity to develop new products and processes, that is, a firm can be inventive independent of the sector to which belongs.

Regarding barriers to innovation, success in the invention phase is positively related with economic/financial barriers, i.e., a firm with a strong perception of economic/financial barriers is likeliest to finish successfully its invention ventures. One

could think that this is a counterintuitive result because if a firm is inventive, how can this firm perceive that economic/financial barriers prevent it from inventing successfully? In the context of our investigation, this can have a consistent explanation. If a firm has success in the initial phase of the innovation process, but this firm cannot profit from those projects, i.e., the appropriation process is not developed correctly, a firm can perceive that its whole effort was meaningless because the firm now has an invention that cannot be taken to market; it is clear that the whole process created new knowledge and maybe other spillovers for the firm and society, but in the short term the firm could perceive that the innovation process was extremely costly. Therefore, it's consistent to find a positive relationship between success in the invention phase and positive cost-funding barriers to innovation.

Table 2: Results of the econometric models

Variables	***Invention phase***				***Appropriation phase***			
	failure		***success***		***failure***		***success***	
	Coef	***P-value***	***Coef***	***P-value***	***Coef***	***P-value***	***Coef***	***P-value***
Barriers:								
eco_fin_barr	0.100**	0.019	0.130***	0.000	0.039	0.136	0.029	0.324
know_barr	0.099**	0.039	-0.061	0.136	-0.040	0.180	-0.032	0.340
market_barr	0.017	0.700	0.058	0.120	0.054**	0.046	0.0326	0.285
Control variables:								
size	-0.146***	0.000	0.203***	0.000	0.048**	0.048	0.228***	0.000
inn_exp	-0.139***	0.000	0.033***	0.000	0.013**	0.002	0.037***	0.000
coopera	-0.268***	0.000	0.483***	0.000	-0.033	0.229	0.472***	0.000
pub_funds	-0.037	0.422	-0.158***	0.000	-0.096***	0.000	-0.021	0.484
group	0.171**	0.002	-0.044	0.372	0.014	0.725	-0.040	0.349
pat	-0.027	0.659	0.597***	0.000	-0.125***	0.000	0.367***	0.000
htec	0.319**	0.002	0.046	0.646	-0.071	0.410	-0.109	0.233
mhtec	0.252***	0.000	0.058	0.288	0.255***	0.000	-0.222***	0.000
_cons	-1,207***	0.000	0.494***	0.000	-0.853***	0.000	-0.186	0.104
Num. obs.	25,987		25,987		25,987		25,987	
Num. firms	3,256		3,256		3,256		3,256	
LR χ^2 (19)	1,029.5		931.9		160.8		1,225.7	
Prob > χ^2	0.00		0.00		0.00		0.00	
Note: For simplification, the results of time-effects dummies are not reported.								

*P. <0.05; **P.<0.01; ***P.<0.001

The fact that knowledge barriers, where not significant for success in the invention phase, can be a signal that in order to successfully develop an innovation, firms have to properly overcome knowledge barriers perceived as relevant when firms fail in the invention phase.

2.4.3. Appropriation phase: failure

The likelihood that a company cannot bring products and processes developed in the invention phase to market is positively related to the size of the firm, that is, the largest SMEs fail more in their attempt to reach the market. So size is a determinant in the

likelihood of success in the invention phase, but it does not guarantee success in the appropriation phase. Likewise, firms with higher innovation expenditures per employee seem to fail more to reach the market. This last result can be related to the size results explained above, because big firms are the ones with highest per-employee R&D&I budget.

Public funds are negatively related to failure to reach the market, i.e., when a firm uses public subsidies for innovation, the probability of failure to bring products to market is reduced; likewise, firms without patent applications are likeliest to fail bringing innovation to market, maybe firms that perceive that it's difficult to reach the market do not try to protect their inventions, because this means cost overruns.

Economic/financial and knowledge barriers are not related to failure in the appropriation phase; however, market barriers are related to this type of failure, so in that sense, the perception that there are big firms competing for markets or that demand for products and processes is uncertain tends to increase the likelihood of firms not reaching the market.

The fact that market barriers alienate firms from their possible clients shows that even companies that are in advanced stages of the process of innovation are not prepared to overcome market impediments or to understand how those impediments can prevent them from successful innovation. The hypothesis that a firm can successfully develop products and processes but not reach the market due to specific barriers was proved (H1): market issues prevent firms from receiving revenue from their innovations.

2.4.4. Appropriation phase: success

Larger companies seem likely to succeed in reaching the market; it seems that bigger firms have a greater likelihood of both failing and succeeding in selling their innovations. This could be due to the fact that a small proportion of small firms reach the appropriation phase, because they tend to fail more in the invention phase, as we showed in section 2.2. Likewise, firms with higher budgets for innovation activities also seem to fail and succeed in bigger proportions in the appropriation phase, and given that firms with low budgets tend to fail more in the invention phase, we believe that this is

because firms with lower budgets tend to reach the last phase of innovation process in smaller proportions.

Regarding cooperation, firms with these types of agreements tend to be more successful than firms without them; this is important, given that open innovation as it was proposed by Chesbrough (2006) is proven to be a fundamental factor for innovation success for SMEs. Given that lack of partners for cooperation is a knowledge barrier, one can see that companies overcoming this impediment are the ones with a greater probability of succeeding in the innovation processes.

Firms with patent applications also tend to be more successful in the appropriation phase. It seems like firms believing that there is a chance of selling their products are those who patent their inventions and try to protect themselves from competition. High and intermediate technology sectors seem to be negatively related to success in the appropriation phase; however, only medium high technology firms are statistically significant. Given that this type of firm tends to fail more in the innovative phase, we believe that this result for the appropriation phase is related to the fact that only a small proportion of firms reach this phase.

Our results show that innovation barriers are not related to success in the appropriation process, that is, firms obtaining revenues from their inventions do not perceive barriers to innovation. We believe that this result confirms that companies succeeding at innovation are those that effectively overcome barriers, or those that never perceive those barriers to be an important issue. In that sense, our second hypothesis (H2) is proved: firms that successfully overcome barriers of all types are the likeliest to benefit from the innovation process.

2.5.Discussion and concluding remarks

We used the Teece (1986) framework to contribute to a holistic view of the relationship between the innovation process and barriers to innovation. Therefore, we divided the process of innovation into two separate stages: the invention phase, where an innovation is conceived; and the appropriation phase, where production and commercialization take place. Likewise, we divided each of those stages into two possible outcomes, failure and

success; our purpose was to understand which innovation barriers were related with this outcome at the firm level.

With regard to the economic/financial barriers, we found that they are related to the initial phases of the innovation process, these results are aligned with Canepa & Stoneman (2002), Galia & Legros (2004), Savignac (2008), Mohnen et al. (2008), D'Este et al. (2012), and Blanchard et al. (2013). Our results show that economic/financial barriers are positively related to success in the invention phase, so firms successfully developing inventions tend to perceive more economic/financial barriers. We argue that this is not a counterfactual result in the context of our research, because firms perceive an innovation process as a costly one if they cannot bring inventions to market and profit from them. We also found that once the invention phase is passed, economic/financial–related barriers become irrelevant. Thus, financial problems seem to be relevant for firms in the beginning of the invention phase, so policy makers should be aware that subsidies for R&D&I are quite important for firms in those phases if they are looking to help firms to overcome economic/financial barriers.

Concerning knowledge impediments, innovation projects are affected by them only at the initial stages of the invention phase, i.e., firms are prevented from finishing their invention projects because of skilled labor, cooperation, and information issues. As it was reported by Galia & Legros (2004) and Mohnen & Rosa (2001), the likelihood of project abandonment rises with the perception of knowledge barriers, and our results are aligned with these outcomes. We also found that once the invention phase is passed, knowledge impediments are irrelevant, so companies work hard at the beginning of their innovation process to find cooperation partners, market knowledge, and skilled labor.

Market barriers seems to be the real impediment for firms regarding their capability to bring their inventions to market; we found that firms perceive those impediments as a real barrier only in the appropriation phase. Consequently, the uncertainty of demand for innovative products and services and market domination by well-established firms are big issues for SMEs that have already developed an invention. In that sense, in order to reduce the uncertainty of their projects, is imperative for firms to determine the

market possibilities for their inventions in the initial stages of the innovation process; this strategy can help them to reduce wasting scare resources.

As we anticipated, our findings support the idea that in order to be successful in the appropriation phase, a firm has to overcome all barriers to innovation. The policy implications of this result are quite significant; the fact that actual policies tend to privilege the invention stage of the innovation process, mainly by subsidizing R&D&I, shows that this could be an incomplete approach. Policies can help overcome innovation barriers in the initial stages of innovation process; however, if those policies do not address the whole process and help firms to overcome all barriers even at the appropriation (commercialization) phase, it is less likely for a firm to be a winner in the innovation process and society can take advantage only of a minor set of innovation spillovers.

The main result of this research is the differentiated impact of each barrier in the different stages of innovation process. Moreover, these differences can be easily rationalized with a dynamic approach to the innovation process, which in general terms can conclude that failure in the invention phase is typically related to economic/financial and knowledge barriers, and that after overcoming this phase, the relevant obstacle is typically market barriers. Finally, a successful innovation in all phases is characterized by the perception of no barriers.

We proposed that firms can be winners as invention developers, but losers when taking those inventions to market. There is a long way from the development of an invention until revenues come through the door, and for companies' interests, this last step is the most important, because it allows them to maximize their value, which is the main objective of private innovation ventures. As we found, market barriers seem to prevent firms from taking their inventions to market, so both policy makers and researchers need to expand their vision of barriers to innovation, including a dynamic approach to the innovation process, because without reaching the market, there is no such thing as innovation.

2.6.Bibliography

Arundel, A., 1997. Enterprise strategies and barriers to innovation. *Innovation Measurement and Policies*, Volume 50, pp. 101-108.

Baldwin, J. & Lin, Z., 2002. Impediments to advanced technology adoption for Canadian manufacturers. *Research policy*, 31(1), pp. 1-18.

Blanchard, P., Huiban, J. P., Musolesi, A. & Sevestre, P., 2013. Where there is a will, there is a way? Assessing the impact of obstacles to innovation. *Industrial and Corporate Change*, 22(3), pp. 679-710.

Canepa, A. & Stoneman, P., 2002. Financial constraints on innovation: A European cross- country study. Kiel Institute of World Economics, Working Paper, pp. 2-11.

Castellacci, F., 2008. Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation. *Research Policy*, 37(6), pp. 978-994.

Chesbrough, H. W., 2006. Open innovation: The new imperative for creating and profiting from technology. 12 ed. Boston, MA, USA: Harvard Business Press.

D'Este, P., Iammarino, S., Savona, M. & Von Tusselman, N., 2012. What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy*, 41(2), pp. 482-488.

Galia, F. & Legros, D., 2004. Complementarities between obstacles to innovation: evidence from France. *Research policy*, 33(8), pp. 1185-1199.

García-Vega, M. & López, A., 2010. Determinants of abandoning innovative activities: evidence from Spanish Firms. *Cuadernos de economía y dirección de empresa*, 13(45), pp. 69-91.

Henttonen, K., Ojanen, V. & Puumalainen, K., 2015. Searching for appropriate performance measures for innovation and development projects. *R&D Management*.

Hurmelinna- Laukkanen, P. & Puumalainen, K., 2007. Nature and dynamics of appropriability: strategies for appropriating returns on innovation. *R&d Management*, 37(2), pp. 95-112.

Iammarino, S., Sanna Randaccio, F. & Savona, M., 2007. The perception of obstacles to innovation. Multinational and domestic firms in Italy. Office of Economic Theory and Application.

Madrid-Guijarro, A., García, D. & Van Auken, H., 2009. Barriers to innovation among Spanish manufacturing SMEs. *Journal of Small Business Management*, 47(4), pp. 465-488.

Mohnen, P., Palm, F., Van Der Loeff, S. & Tiwari, A., 2008. Financial constraints and other obstacles: are they a threat to innovation activity? *De Economist*, 156(2), pp. 201-214.

Mohnen, P. & Rosa, J., 2001. Les obstacles a l'innovation dans les industries de services au Canada. *L' actulité économique*, 77(2), pp. 231-254.

Pellegrino, G. & Savona, M., 2013. Is money all? Financing versus Knowledge and Demand Constraints to Innovation. UNI-MERIT Working Paper Series, Volume 29.

Pérez-Cano, C., 2013. Firm size and appropriability of the results of innovation. *Journal of Engineering and Technology Management*, 30(3), pp. 209-226.

Savignac, F., 2008. Impact of financial constraints on innovation: what can be learned from a direct measure? *Econ. Innov. New Techn.*, 17(6), pp. 553-569.

Segarra-Blasco, A., García-Quevedo, J. & Teruel-Carrizosa, M., 2008. Barriers to innovation and public policy in Catalonia. *International entrepreneurship and management journal*, 4(4), pp. 431-451.

Silva, M. J., Leitao, J. & Raposo, M., 2008. Barriers to innovation faced by manufacturing firms in Portugal: how to overcome it for fostering business excellence? *International Journal of Business Excellence*, 1(1-2), pp. 92-105.

Teece, D. J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy*, 15(6), pp. 285-305.

Tourigny, D. & Le, C. D., 2004. Impediments to innovation faced by Canadian manufacturing firms. *Economics of Innovation and New Technology*, 13(3), pp. 217-250.

Chapter 3. Show me the money: pecking order and funding sources for innovative firms in Colombia

3.1. Introduction

The well-known theory of capital structure introduced for Modigliani & Miller (1958), proposed that the differences in capital sources used for firms to support their investment options have no impact in the value of firms. Basically, this theory suggests that in a market without failures, a firm will be indifferent to all the possible capital sources because the implicit cost for each of those sources will be equal; i.e., a firm could use cash flow, debt, equity or even venture capital, and the firm value will remain invariant.

Generally, the MM theory has been rejected given that corporate and personal taxes affect a firm's capital structure; in the same direction, the presence of information asymmetries, agency costs and adverse selection issues create differences among the cost of diverse firms' funding sources; i.e., a firms' decision about the use of one or another capital source could diminish or elevate the cost of that firms' capital and therefore the value of the company (Myers & Majluf, 1984; Myers S. C., 2001).

Given market failures, an important theory of capital structure based in the existence of those failures was proposed by Myers & Majluf (1984). This theory, so called "Pecking Order theory (POT)", suggests that, in presence of information asymmetries and adverse selection issues between firm managers and outside investors, firms will prefer internal over external funding for their ventures. However, if internal resources are scarce, a firm would have to seek available external resources, i.e., debt or equity funding. Assuming that in most of the cases debt funding is cheaper than equity (caused by the agency costs raising the risk of equity funding), a firm will select debt financing over equity, therefore, when a firm need to finance a new investment, it will select funding sources in a hierarchical order, first internal sources, then debt and finally equity.

Although the pecking order theory was developed to understand the way firms finance their capital assets, some researchers have focused on the capital structure of firms' intensive on R&D and innovation activities, or in the capital structure of high technology startups. Academic results seem to be contradictory; some found that firms finance their R&D and innovation activities as described in the pecking order theory (Manigart & Struyf, 1997; Giudici & Paleari, 2000; Ullah, et al., 2010; Bartolini, 2013; Hummel, et al., 2013), however, some others found evidence of a new form of pecking order (Aghion, et al., 2004; Schäfer, et al., 2004; Sau, 2007; Minola & Cassia, 2013).

This new form of pecking order theory suggests that high tech, innovative or new technology-based firms, strongly use internal resources as a main financial source, just like in the usual pecking order theory; but, in respect to external resources, equity is preferred over debt because innovative firms cannot access debt markets. In that sense, some studies have shown that innovative firms tend to be credit-constrained because of moral hazard and adverse selection issues regarding their innovation activities (Freel, 2007; Colombo & Grilli, 2007; Bartolini, 2013), and in some cases, debt markets are not willing to leverage innovative ventures because of the long-term focus of those endeavors, the high proportion of intangible assets used, and the uncertainty related with innovation profits. In those cases, a firm with a strong focus on innovation activities, or a high technology firm, will first use cash flow, then equity and debt as a final option (Aghion, et al., 2004; Schäfer, et al., 2004; Ullah, et al., 2010; Minola & Cassia, 2013; Bartolini, 2013) creating an altered form of pecking order theory (APOT).

In most of the cases, the evidence about an APOT has been found in developed countries in which firms' possibilities to raise equity are higher than in other types of countries with illiquid capital markets, or in countries in which the venture capital funding is strong compared with underdeveloped countries. In order to raise venture capital or equity from markets, firms need to be supported by a liquid and specialized capital market to undertake an Initial Public Offering (IPO), or to provide the necessary conditions for an exit strategy for early venture capitalists (Hall & Lerner, 2010). In that sense, research carried out in developed countries about the way innovative firms fund their ventures could be biased; it is possible that the financial behavior of firms in underdeveloped countries, with a small and illiquid equity markets, differ from those in developed countries.

This chapter attempted to reach two goals. First, to determine the main characteristics of firms' funding innovation with internal resources, bank credit, equity, government grants, and other funding sources in Colombia, and second, to find the likelihood for Colombia's firms to fund their R&D and innovation ventures with those same financial sources. We wanted to determine if in a developing country like Colombia, the POT or the APOT capital structures are followed by firms to finance their R&D and innovation activities.

This is a novel approach to the financing of innovation in the sense that we are using only data from a national innovation survey (EDIT), in which questions about the way firms fund their R&D and innovation activities are included and, because we are trying to understand if R&D and innovation activities have a relevant role in the way firms use internal and external funding sources. Data includes firms from the manufacturing sector of Colombia from 2007—2008, and we use a multivariate probit approach to take into account the simultaneity of the innovation-funding phenomenon.

This chapter is divided as follows. Section 3.2 includes a review of the pertinent literature and a small analysis of financial market development in Colombia and in the countries in which POT and APOT research has been developed; In Section 3.3, data, methodology, and expected results are developed. In Section 3.4, the results for the econometric model are described, and in Section 3.5, we developed the main conclusions of the report.

3.2.Literature Review

In 1958, Modigliani & Miller (MM) proposed that under equilibrium, given that agents have the possibility of perform arbitration, the value of a levered and an unlevered firm will be the same. According to them "… *the cut-off point for investment in the firm (...) will be completely unaffected by the type of security used to finance their investment*" (Modigliani & Miller, 1958; p. 288). The logical conclusion to which this postulate takes us is that firms could raise money from any given financial source, the cost of capital for each firm will be the same, and all firms will have the same access to capital (Myers S. C., 2001). However, the fact that the MM thesis was framed in an equilibrium market without corporate taxes or agency costs, and with symmetric information, has

led to the rise of new capital structure theories in which imperfect market characteristics are included.

Tradeoff theory (TOT) developed by Kraus & Litzemberg (1973) builds on MM propositions and includes the effect of corporate and personal taxes, but also bankruptcy costs; the TOT implicates that there is an optimal point of debt in which managers maximize the value of a levered firm. This can be done by maximizing the debt tax shield and minimizing the bankruptcy costs; over this point, if a firm acquires more debt, the value of the levered firm will be lower than the unlevered one. Even so, firms can choose not to pursue the maximizing point of value through debt, because sometimes they prefer to fund their ventures with other sources like cash flow or equity (Myers S. C., 2001).

The Pecking Order Theory (POT) (Myers & Majluf, 1984), assumes a market in which there are information asymmetries between managers and investors. In this context, a manager's decision to issue equity to finance a new venture provides information to investors about an overvalued company because managers only will issue shares when they can maximize the amount of cash received by the sell. Then, the direct effect of an equity issue in this context is the fall in stock prices. In the same framework, if a firm can use debt or equity to finance their ventures, an investor would understand that an equity issue is made by managers to transfer the risk to new stockholders[1], therefore, investors will understand that equity acquisitions are not a good idea. As a result, the POT claims that firms will prefer internal rather than external sources of finance because there are no information asymmetries inside the firms; when external sources are needed, firms will prefer debt over equity, this is, the safest and cheapest finance sources first.

At the same time, although the POT was developed to understand the way all types of firms fund their capital assets, some researchers have focused on the capital structure of intensive R&D and innovation firms to explore if, for those kinds of companies, the POT is supported. According to Hall & Lerner (2010), the market failures are stronger for innovative and high technology firms; in the first instance, innovation is riskier and

[1] Managers cannot transfer risk to lenders given that lender rights are prior to equity holders rights.

longer-term compared with traditional capital investments. Consequently, the profit rate required by external investors is higher than in other types of endeavors because of the uncertainty of the projects. In that sense, one can expect innovative firms to be highly financed by internal funding.

At the same time, when innovative firms have to rely on external funding, asymmetric information is a major issue for those companies; the fact that firms have better information about the real possibilities of their ventures elevates the cost of external funding. To solve this issue, one might think that full revelation of the innovative venture could be a solution, but in that case, the innovator could be imitated by its competition (Hall & Lerner, 2010). Simultaneously, innovative companies have lower rates of collateral assets to support debt, i.e., the main objective of those firms is to create knowledge embedded in new products or services; the asset in which firms support the knowledge creation is human capital that cannot be used as debt collateral, and therefore, it's expected for innovative companies to be credit-constrained because they do not have collateral assets (Freel, 2007; Colombo & Grilli, 2007).

For these reasons, it was expected that innovative firms tend to prefer internal, over external sources to finance their activities. Nevertheless, innovation activities are costly and therefore, firms tend to raise money externally. However, given that high technology and innovative firms could be credit constrained, some firms will prefer to finance their projects with equity rather than debt, giving room to an altered form of pecking order (APOT), in which firms prefer internal over external sources, but equity over debt financing[2]. In this area, research results seem to be contradictory. Some research found that firms finance their R&D and innovation activities as described in the POT (Manigart & Struyf, 1997; Giudici & Paleari, 2000; Ullah, et al., 2010; Bartolini, 2013; Hummel, et al., 2013), while others found evidence of an APOT for firm's intensive on R&D and innovation activities (Aghion, et al., 2004; Schäfer, et al., 2004; Audretsch & Lehmann, 2004; Ullah, et al., 2010; Minola & Cassia, 2013).

For instance, Manigart & Struyf (1997), working with their own developed survey for 18 Belgium firms, found out that there's evidence of a capital structure under the POT

[2] For a complete description of the Altered Pecking Order phenomena, review the work of Sau (2007).

parameters for high technology companies, and that firms tend to have lower proportions of collateral assets in which credit rationing will appear; they worked also with government as a source of finance, finding out that there was little effect of the latter over capital structure of high technology firms. Giudici & Paleari (2000) used data from 46 high technology Italian SMEs, and by means of a direct survey they concluded that those firms had a capital structure like POT predicts. Also for Italy, Bartolini (2013) used a data combination between the Community Innovation Survey (CIS3[3]) and an administrative survey for 2.591 firms between 1.996 and 2.003, and determined that firms follow the POT capital structure characteristics. They also found that the way firms fund innovation depends mainly on specific characteristics such as size, age, localization, or innovative behavior. Ullah, et al., (2010) found out that in the United Kingdom, firms belonging in the software industry followed the POT capital structure, and that some firm characteristics such as industrial belonging could define the way firms fund their ventures. Lastly, Hummel, et al., (2013) used data from 171 surveyed SMEs from Germany. They found out that the innovativeness degree of a firm had an impact in the way companies are financed. Also, they confirmed that for that group of firms, their capital structures were like the POT predicts.

On the side of the APOT for innovative and high technology firms, Aghion, et al., (2004) used 900 firms from the London Stock Exchange and found that intensive R&D firms have different financial behaviors than other types of companies, because those firms tend to use more debt than firms with low levels of R&D expenditures. In the same direction, they found that firms with the highest levels of R&D expenditure are likeliest to fund ventures with equity than with debt, confirming the existence of an APOT. At the same time, Audretsch & Lehmann (2004), using data from 341 German traded firms, found out that growing high technology firms tended to privilege external equity over external debt, and that those sources were not complementary, but were substitutes.

In the case of Ullah, et al., (2010), although they found that in the United Kingdom the software firms followed a POT pattern, they used data for 42 software firms and 41 biotech firms, showing that biotech firms, contrary to software firms, have an APOT

[3] For a complete description of the Community Innovation Survey, review Arundel, et al. (2008)

capital structure, concluding that some industry characteristics could influence the way innovative firms fund their ventures. In the same sense, Minola & Cassia (2013), working with data from 5,000 firms from the Kauffman Firm Survey, found out that the most innovative firms tended to have an APOT capital structure pattern. However, they also found that firm characteristics tended to define the way they funded R&D expenditures. In the case of Germany, although they were not working within the APOT framework, Schäfer, et al. (2004) used data from 903 firms involved in government innovation programs and found out that firms willing to finance their ventures with equity sources are the riskier ones, suggesting that when the expected return is high, firms and investors are willing to use shares to finance their projects in detriment of debt funding sources.

One major issue about some of this research about capital structure, especially the ones supporting an APOT capital structure for innovative firms that focus on U.S., U.K., and German firms, in part because the availability of data for those countries, is well-known; that financial markets in those countries are well-suited for venture capital and equity funding (Hall & Lerner, 2010; Kerr & Nanda, 2015). Moreover, in the case of Aghion, et al., (2004), and Audretsch & Lehmann, (2004) research, they used publicly traded firms in the United Kingdom and Germany, however, those kinds of firms are an exception, especially for underdeveloped countries. Capital markets in those countries are illiquid, have a low transactional volume, and have a small set of traded firms.

In Table 3 it is possible to appreciate those differences for OECD members, Colombia, Belgium, Italy, Germany, United Kingdom and United States. Between 2000 and 2009 we used that particular set of countries given these are the ones related to the literature reviewed in past paragraphs, and we add the OECD members to develop a comparison context. With Table 3 data it is possible to appreciate that Colombia as an underdeveloped country and has an embryonic capital market. Capitalization of listed domestic firms is low compared with OECD, and the United Kingdom and the United States. For the years 2008 and 2009, Colombia had higher market capitalization as a percentage of GDP than Belgium, Italy and Germany. However, this could be a consequence of the subprime crisis in developed countries in which Colombia's market grew as a consequence of the inflows of international investment. Nevertheless, in 2005 and 2006 the market capitalization of Colombia was low in comparison with those

countries. The number of listed firms also showed that Colombia's market is small in comparison with those of developed countries; for instance, Colombia has two firms per million inhabitants listed in year 2000 compared with 35 in the United Kingdom. Lastly, the total value of stocks traded in the market as a percentage of the GDP was 9.6% in Colombia's best year against 220,7% of the United States in the same year. The point here is that if the development level of capital markets is related to the finance sources that innovative firms can raise, we expected equity funding for innovative companies to be restricted given the low liquidity and volume of their capital markets.

Table 3. Capital markets of selected countries and the OCDE

Market capitalization of listed domestic companies (% of GDP)										
	2000	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***
OECD	108.4	94.2	75.8	89.6	95.0	99.3	112.4	110.4	58.1	81.0
Colombia						34.5	34.6	49.2	36.0	60.1
Belgium	76.7	69.7	49.3	54.4	73.7	74.5	96.7	81.7	32.2	53.6
Italy	67.3	45.4	37.7	39.2	43.9	43.1	52.8	48.7	21.8	30.0
Germany	65.1	54.9	33.0	43.1	42.4	42.0	54.5	61.2	29.6	37.8
U. Kingdom	165.7	139.9	110.5	124.8	122.5	126.4	146.1	129.5	66.9	
U. States	146.9	131.7	100.7	123.9	133.0	129.8	141.2	137.6	78.7	104.6
Listed domestic companies, per million inhabitants										
OECD	20.8	20.7	20.0	21.2	18.5	18.5	21.6	21.7	21.0	20.0
Colombia	1.8	2.9	2.6	2.6	2.5	2.3	2.1	2.0	2.0	1.9
Belgium	25.9	26.7	24.8	24.1	22.6	21.2	19.4	16.5	16.0	15.3
Italy	5.2	5.2	5.2	4.7	4.7	4.7	4.9	5.2	5.0	4.9
Germany	9.0	9.1	8.7	8.3	8.0	7.9	8.0	9.3	9.0	8.6
U. Kingdom	41.2	41.2	40.5	38.7	41.4	45.6	47.9	42.2	39.1	35.0
U. States	24.5	21.7	19.8	18.3	17.8	17.4	17.2	17.0	15.3	14.3
Stocks traded, total value (% of GDP)										
OECD	160.4	118.7	91.7	83.3	91.5	112.6	134.3	177.3	166.3	127.5
Colombia	1.2	0.8	1.1	0.9	1.8	6.5	9.6	8.3	7.4	8.5
Belgium	16.2	15.9	14.7	13.0	20.3	27.5	33.0	49.1	36.8	25.4
Italy	86.7	51.6	45.5	46.7	50.1	56.9	62.2	100.5	57.9	42.4
Germany	93.7	66.7	41.9	40.6	41.9	45.0	65.0	94.6	111.7	52.3
U. Kingdom	117.9	123.3	62.3	64.1	70.6	71.5	106.8	132.9	97.9	121.3
U. States	289.6	196.6	155.3	139.4	155.6	197.0	220.7	296.0	321.0	237.9

Source: World Bank Databank, author's calculations

At the same time, research in which publicly traded firms were used, tended to use a small set of surveyed firms, contrary, when CIS data were used, a great number of firms can be used. For instance, Bartolini (2013) used data for 2.591 firms based on the Community Innovation Survey (CIS) for Italy, this survey had access to a more comprehensive set of data about innovation activities, and not only the R&D firm expenditures, which is the most common innovation proxy used on research with publicly listed companies.

Simultaneously, research using publicly listed firms tend to use a complete set of financial reports of these companies, including profits and losses, cash flows, and balance sheets statements. This because researchers do not have access to data about the financial behavior of firms related directly with R&D and innovation activities. The problem with the use of full financial reports is that in a majority of cases, researchers only can make assumptions about the financial behavior of firms regarding innovation activities, i.e., financial reports can only give us information about the amounts of debt and equity in a general view, including innovative and non-innovative activities. However, innovation usually does not follow the logic of firms' general activities; so, one can expect that the financial behaviors of firms regarding innovation would be slightly different from the financial reports data. In that case, it could be interesting to have data about the way firms finance their innovation activities and relate that information with the innovative behavior of companies. Unfortunately, it is not common to find this information jointly, because the innovation surveys following the Oslo manual (Mortensen & Bloch, 2005), do not include questions about the financial behaviors of firms.

The present research is a novel effort in the sense that we used data from Colombia's innovation survey, in contrast with other national innovation surveys, and combined questions about innovative behavior and the sources of funding to develop innovation ventures. As we know, only one effort has been developed to use this type of information to determine the way firms finance their innovation activities. It was developed by Sierra, et al. (2009) for the Bogotá (Colombia) region; in this research, they found that internal resources and national banking, followed by government grants, were the main funding sources for innovative firms. However, the inexistence of an equity source in data does not allow them to probe the existence of a POT or an APOT capital structure. In this research, we tried to determine, in the first instance, if the main characteristics of firms using the different funding sources, could define the way that firms finance their innovative efforts, and second, corroborate if Colombia's innovative firms followed the POT or APOT capital structure.

3.3.Data, methodology and expected results

The Colombia´s EDIT [4] survey followed the general guidelines of the European Community Innovation Survey, but has a special chapter in which firms are asked about the funding sources used for innovation activities. Among the sources the EDIT includes are internal resources, bank debt, equity, government funds and others[5]. Given that in the reviewed literature one cannot find a source of information including data about innovation activities by one side, and data about the way firms finance those innovation activities on the other, the EDIT survey is a special case that can be reviewed to understand the way firms' funds innovation related activities, specially, if one is interested in the behaviors of innovation companies in underdeveloped countries.

We used the 2007–2008 EDIT results, that includes 7.683 manufacture firms of which 67.3% are firms between 1 and less than 50 employees, 25.1% are firms with at least 50 and 250 employees and 7.6% are firms with more than 250 workers. However, we only used companies with positive expenditures on R&D and innovation, and restricting data of firms with less than 10 employees and therefore, our final sample is 2.621 firms. In that sample, 16.3% are big firms with more than 250 employees, 39.9% have between 50 and 250 employees, and 43.9% have between 10 and 50 workers.

Firms in our sample were asked about the origin of funds used to support R&D and innovation activities, therefore, we characterized the innovation funding sources for the sample. We used dummy (1;0) variables to identify when a firm was using or not using a specific funding source. As we can see in Table 4, internal funding was the most used resource in all firms followed by banks. Specially drew our attention the fact that equity is not the third most used source of funding; government grants and other sources represented 3.1% and 3.2% against 2.0% of equity. Medium size firms were the ones with the most frequent use of equity, however, for this type of firms, the sum of government grants, and other sources represented almost 3 times the frequency of use against equity. Large companies were the ones that use most frequently internal resources, banks, and government grants.

Table 4. Funding source used by firm size

[4] Manufacture industry survey for technologic development and innovation (Encuesta de desarrollo e innovación tecnológica de la industria manufacturera)

[5] Includes cooperation, economic group, and other nonrelated firms funding.

Size	*#*	*Internal funds*	*Banks*	*Equity*	*Public grants*	*Others**
All Sample	2,621	87.8%	29.7%	2.0%	3.1%	3.2%
Small >10; <50	1,150	87.5%	26.8%	1.8%	1.7%	2.9%
Medium >=50; <=250	1,045	87.5%	31.7%	2.4%	3.4%	3.8%
SMEs (>10; <=250)	2,195	87.5%	29.1%	2.1%	2.5%	3.3%
Large (>250)	426	89.7%	32.4%	1.4%	6.1%	2.3%

* Includes international cooperation, economic group and other non-related firms
Source: EDIT 2007-2008.

In Table 5 the tetrachoric correlations for the dummy variables of funding sources are shown; it seems evident that decisions for taking one type or other of a funding source are correlated, e.g., the use of internal sources is negatively correlated with banks, equity, public grants, and other type of funds. Bank funding is positively correlated with equity and other sources, etc. In this case, one can argue that this is a logical outcome; firms do not use an exclusive funding source, but a combination of them, so a specific company can use internal funding, banks, and government funding at the same time, and all the possible combinations of those sources. In the same sense, a firm's decision to use one of the funding sources can be affected by the likelihood they have access to another funding source. In that direction, we also performed a multivariate test for covariance to determine if funding sources are jointly decided by firms, specifically, we used a likelihood ratio test to review if the variance-covariance matrix is a diagonal one or if the matrix contains significant covariance among variables. The test results showed that funding sources are strongly related among them[6]. This result had implications in the econometric strategy used for our research, because if the funding sources fluctuated jointly it was necessary to use a multivariate approach. Therefore, and given that we are using dummy variables for funding sources, we decided to use a multivariate probit model following the strategy of Cappellari & Jenkins (2003).

Table 5. Tetrachoric correlations of funding sources

	internal	*bank*	*equity*	*public*	*Other sources***
internal	1				
bank	-0.7743*	1			
equity	-0.5505*	0.1813*	1		
public	-0.1870*			1	
Other sources*	-0.3006*	0.1425*		0.2389*	1

* Only correlation with 5% significance level are shown.
**Includes international cooperation, economic group and other non-related firms.
Source: EDIT 2007-2008.

[6] The adjusted LR chi^2 was 754.02 and prob> chi^2=0.0000

The variables used in the model are summarized in Table 6. We included five dependent dummy variables to cover all the funding sources used by firms in order to finance their R&D and innovation activities. The independent variables included can be divided into two groups, the expense vector (X_j) and the firm characteristics vector (Z_j). The expense vector includes four variables counting for 1 if the firm had an expense of that type (internal or external R&D, intangible innovation, tangible innovation, and biotechnology expenses), and 0 otherwise. The firm characteristics vector included a log of the firm size, a dummy variable for capital origin of firms, a dummy variable counting if a firm is innovative or not, a variable equal 1 if firms have strong financial barriers perception, a sectorial dummy variable for firms of high technology industry () and lastly, a proxy variable for innovative revenues.

Table 6. Variables used in the multivariate probit models

Variable name	***Type***	***Description***
internal	Binary	1 if firm is using internal funding to support its R&D and innovation expenditure, 0 otherwise.
Bank	Binary	1 if firm is using bank funding to support its R&D and innovation expenditure, 0 otherwise.
equity	Binary	1 if firm is using equity funding to support its R&D and innovation expenditure, 0 otherwise.
public	Binary	1 if firm is using government grants to support its R&D and innovation expenditure, 0 otherwise.
other_sources*	Binary	1 if firm is using international cooperation, economic group or other firms funding to support its R&D and innovation expenditure, 0 otherwise.
randd	Binary	1 if firm has any expenses on internal or external R&D, 0 otherwise
intangible	Binary	1 if firm has any innovation expenses on intangible assets (Innovation marketing, technology transfer, technical assistance and consulting, industrial design or education and training), 0 otherwise
tangible	Binary	1 if firm has any innovation expenses on tangible assets (Machinery and equipment, Information and telecommunication technologies), 0 otherwise
biotech	Binary	1 if firm expend any amount of money on biotechnology activities, 0 otherwise
Size	Log	Is the log of average number of employees of firms between 2007 and 2008
foreign	Binary	1 if firm has international origin, 0 otherwise
innovative	Binary	1 if in the past two years' companies developed any product, services or process innovation new to the firm or new to the market, 0 otherwise
fin_barr	Binary	1 if firm perceived that it has difficulties to access internal or external funding sources or if firm perceived that innovation is not profitable, 0 otherwise. We categorize as 1 only firms reporting a strong perception of impediments
hightech	Binary	1 if firm belongs to a high technology sector, 0 otherwise (see Appendix A)

Variable name	*Type*	*Description*
rev_prox	Percentage	Proxy of the innovation revenues. Given that innovative revenues data is not available into the survey, if a firm respond that innovative products and services sales are 25% of their national sales and 10% of their international sales, the proxy variable will take the 0,35 value. It is a proxy in the sense that account for the sum of national and international innovation revenues percentage; a firm in which all their revenues came from innovative products and services will take the value of 2, but if a firm have no innovation revenues in the country or overseas, the proxy will take the 0 value.

* Includes international cooperation, economic group and other non-related firms.

The multivariate probit model (Green, 2003) could be described as:

$$Y_{i,j} = \begin{cases} 1 \; if \; Y_i^* > 0 \\ 0 \; otherwise \end{cases}$$

in which *i* are the five different funding sources described in Table 6, and *j* are each one of the firms included in our sample with,

$$Y_1^* = X_j\beta_{1,1} + Z_j\beta_{2,1} + \varepsilon_1$$

$$Y_2^* = X_j\beta_{1,2} + Z_j\beta_{2,2} + \varepsilon_2$$

$$Y_3^* = X_j\beta_{1,3} + Z_j\beta_{2,3} + \varepsilon_3$$

$$Y_4^* = X_j\beta_{1,4} + Z_j\beta_{2,4} + \varepsilon_4$$

$$Y_5^* = X_j\beta_{1,5} + Z_j\beta_{2,5} + \varepsilon_5$$

Y_i^*, X_j is the expense vector, and Z_j is the firm characteristics vector. And with,

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{bmatrix} | X, Z \backsim N \left(\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{1,2} & \rho_{1,3} & \rho_{1,4} & \rho_{1,5} \\ \rho_{1,2} & 1 & \rho_{2,3} & \rho_{2,4} & \rho_{2,5} \\ \rho_{1,3} & \rho_{2,3} & 1 & \rho_{3,4} & \rho_{3,5} \\ \rho_{1,4} & \rho_{2,4} & \rho_{3,4} & 1 & \rho_{4,5} \\ \rho_{1,5} & \rho_{2,5} & \rho_{3,5} & \rho_{4,5} & 1 \end{bmatrix} \right)$$

Along with the reviewed literature (Aghion, et al., 2004; Ullah, et al., 2010; Bartolini, 2013; Hummel, et al., 2013; Minola & Cassia, 2013), we expected that the firm characteristic vector (Z_i), determines the way firms use funding sources, i.e., characteristics like size, innovation results, capital origin, industry, revenues from innovation, and the perception of financial barriers[7] influence the use of innovation financial sources. In the same direction, we expect the expense vector (X_i) to be related with the funding sources used by firms, i.e., if a firm made an expenditure on R&D,

[7] Innovation surveys based on the Oslo manual generally include a chapter in which firms are asked about their perception of some impediments with regard to innovation activities. Among the impediments asked to firms in Colombia's innovation survey it can be found the perception to financial barriers including i- difficulty to access internal financial funds; ii- difficulty to access external financial funds and iii- innovation is not profitable.

biotechnology, tangible or intangible innovation, this could determine the access to those financial sources, Manigart & Struyf (1997). As we pointed in the literature review, Aghion, et al., 2004, found that intensive R&D firms tended to behave differently from those non-R&D intensive firms regarding their funding sources.

To determinate if innovative firms tended to follow a POT or an APOT capital structure, after the multivariate probit regression, we determined the marginal predicted probabilities of firms to use internal, bank, equity, public grants, or other sources using the Cappellari & Jenkins (2003) strategy. We expected that in Colombia, firms tended to follow the POT structure, given that in underdeveloped countries firms do not have easy access to equity markets, as posted in the literature review and shown in Table 3. So, we expected that firms tended to use internal sources in the highest proportion, followed by banks, and then equity sources; at the same time, related with the use of public grants and other sources, we predicted probabilities would be lower than internal and bank sources. We were also interested in changing the subsamples of firms to determinate if some sets of firms had different capital structures or had the highest likelihoods of being financed by some of the funding sources. Consequently, we ran the same econometric approach for SME's, big firms, innovative companies, and firms with lower and higher R&D and innovation expenditures.

3.4.Results

3.4.1. Results from the full sample

In Table 7 we present the results of the multivariate probit model in which we included all the 2.621 firms from the sample. These results show that firms with positive expenditure in R&D (randd) and firms with expenditures on intangible assets (intangible) tend to finance innovation ventures mostly with their own resources. As it was shown in the literature review section, firms facing higher information asymmetries, tended to use internal resources because the external financing is costly for them. In the cases of intensive R&D firms, the long-term natures of their projects and the uncertainty of future profits elevates the cost of external funding. In the same direction, firms strongly investing on intangible assets cannot provide guarantees of future payments in the case of bank access, making companies rely mainly on internal funds.

Table 7. MPR, funding sources of R&D&i+

Variable	*internal*	*bank*	*equity*	*public*	*other sources*
Randd	0.276**	0.056	-0.06	0.229*	0.144
Biotech	-0.046	-0.116	0.205	-0.124	-0.284
intangible	0.332***	0.006	0.298*	0.273*	0.092
tangible	-0.217	1.024***	0.011	0.176	-0.002
Size	-0.038	0.089***	-0.016	0.172***	-0.006
Foreign	0.203	-0.327***	-0.268	-0.116	0.092
innovative	-0.075	0.448***	0.207	-0.112	-0.12
fin_barr	-0.115	0.238***	0.181	0.075	0.063
hightech	0.353	-0.382*	-0.27	0.09	-0.053
rev_prox	-0.027	0.021	0.062	-0.019	0.037
_cons	1.511***	-2.466***	-2.647***	-2.941***	-1.921***
Predicted Prob.	0.8802	0.2989	0.0200	0.0309	0.0314
N	2621				
Prob>Chi 2	0.0000				

+Multivariate Probit regression. Includes all the sample. Firms with more than 10 employees and with R&D&i expenses in the 2007-2008 period
*P. <0.05; **P.<0.01; ***P.<0.001

We were expecting that firm characteristics were determinant to the use of internal funds. For example, small firms tended to be riskier than bigger firm, and therefore, we expected a negative statistical relationship between internal funds and size. However, size, innovation revenues, or innovation, seem to be irrelevant in the case of internal sources. It appears that firms' characteristics do not determine the use of internal funds after being controlled by the type of spending made by firms.

Bank funding is the contrary case. The type of spending relevant for this type of funding are tangible assets (equipment and machinery, etc.), therefore in the case of debt, the collateral capability of firms is fundamental. Related with the firm characteristics vector, bigger firms tended to use more banks, maybe this caused their expected cash flows and amount of total assets to allow those firms to have easier access to bank funding. In the same direction, innovative firms tend to have more access to bank funding, a possible explanation is that these firms could prove to banks their projects could be successfully finished, or because those types of firms are more active in the search for external funding. However, this aspect has to be researched deeply in the future.

At the same time, firms facing financial barriers, i.e., perceiving a strong difficulty finding internal or external funding and tended to have more banking access; although this result seems to be counterintuitive, there is a strong background of literature supporting that innovation, and barriers can be viewed as firms' experience measure on

innovative markets (Arundel, 1997; Baldwin & Lin, 2002; Iammarino, et al., 2007; D'Este, et al., 2012), so this result can be viewed as if companies having strong financial barriers were the ones having to make higher efforts to access bank loans because they know innovative and financial markets better than other firms.

Firms belonging to high technology industries seemed to be credit constrained. i.e., there was a negative relationship between those industries and bank funding. As it was established by Giudici & Paleari, (2000), it seemed like banks restrict the amount of loans to high technology firms because bank ability to evaluate those kinds of ventures is poor; this is, the market imperfections are stronger for firms in high technology industries.

At the same time, foreign capital firms seemed to be negative related with bank funding; the fact that these types of firms could have access to the financial arm of their international headquarters, possibly decreased the need to access bank loans. In this point, we tried to run a regression separating group funding sources form an "other sources" variable, trying to determinate if foreign firms used group sources in higher proportions. However, the result was not significant.

The use of equity sources is related with intangible assets expenditure. As we posted before, firms with intangible expenses were also prone to use internal sources, and firms with tangible assets were likely to use banks. The fact that firms with intangible assets expenditure used more internal and equity sources could be a clue for a possible existence of an APOT structure for these types of firms. However, as we can see with the marginal probabilities, this is not the case.

Results for public grant funding show that in Colombia's case, this type of funding is not closing the gap between SMEs and big companies; bigger firms, that in theory are the ones confronting less market failures, are likeliest to use government grants. At the same time, firms investing in R&D and intangible assets are likeliest to use public grants. In the case of other sources, we found that no independent variables were significantly related with those sources.

To understand if innovative firms in Colombia follow a POT or an APOT capital structure, we calculated marginal probabilities for each of the dependent variables of the multivariate model. As seen in Table 7, a firm likelihood of using internal funding is 88%, followed by banks with 30%, other sources 3.1%, public grants 3.1%, and finally equity funding with a 2.0% probability. Firms tended to follow a POT capital structure with little likelihood of using equity sources. Firms use internal resources in higher proportion mainly because the market failures elevate the external cost of funding; then, if internal resources are not enough to finance their ventures, firms have to look for external resources. In that direction, bank funding is important for firms even when it is costly, and public and other sources are more likely to be used than equity. Our explanation for the latter result is that in underdeveloped countries the liquidity and access to capital markets are very poor. In that sense, companies could prefer to use equity over banks in some cases and present an APOT capital structure. However, the fact that the capital market is illiquid and small (Table 3), does not allow firms to access equity funds, leaving companies with a POT capital structure in which public and other funding sources are better suited than equity sources for innovative ventures.

3.4.2. Sub-sample results

In order to perform a robustness check, we decided to divide the sample into a number of subsamples. In the same sense, we were interested in determining if some sets of firms have different probabilities to be funded by diverse financial sources included in the survey.

First, we used a subsample of SMEs, and the results remained unchanged, as can be seen in Table 8, a firm likelihood to be financed with internal funds, banks, equity, and other sources remained practically unaltered. However, there was a slight difference in the probability of being financed by public grants from 3.1% for the complete sample against 2.5% of SMEs, so it can be seen that small firms were, to some extent, constrained by public grants. We also used a subsample for big firms, however it cannot be said that regression coefficients were different from zero. For this reason, the marginal probabilities had to be interpreted with caution; still, the fact that likelihood of big firms being funded with public grants was more than two times the likelihood of small firms, could reinforce the fact that SMEs had limited access to public funds. In the

same direction with a probability of 33%, it seems that big firms had more access to bank funding against 30% of SMEs.

Table 8. MPR for SMEs and big firms+

Sub-sample of SME Firms (10-249 employees)					
Variables	**internal**	**bank**	**equity**	**public**	**other sources**
randd	0.259**	0.106	0.047	0.338**	0.225
biotech	0.006	-0.149	0.104	-0.319	-0.244
intangible	0.303***	0.05	0.336*	0.312*	0.14
tangible	-0.197	1.038***	0.049	0.292	0.071
size	-0.029	0.087*	-0.021	0.184*	0.072
foreign	0.284	-0.434***	-0.29	-0.371	0.191
innovative	-0.094	0.551***	0.225	-0.104	-0.143
fin_barr	-0.077	0.225***	0.215	0.107	0.064
hightech	0.29	-0.426**	-0.195	0.092	-0.008
rev_prox	-0.025	0.021	0.043	-0.038	0.026
_cons	1.444***	-2.563***	-2.660***	-3.106***	-2.284***
Predicted Prob.	0.8771	0.2952	0.0217	0.0250	0.0332
N	2,195				
Prob>Chi 2	0.0000				
Sub-sample of big firms (250 or more employees)					
Variables	**internal**	**bank**	**equity**	**public**	**other sources**
randd	0.274	-0.099	-0.634	0.000	-0.109
biotech	-0.382	-0.017	0.822*	0.262	-3.473
intangible	0.347	-0.12	-0.066	0.079	-0.251
tangible	-0.115	0.880*	3.688	0.016	-0.647
size	-0.199	0.094	0.36	0.108	0.19
foreign	0.116	-0.297*	-0.213	0.076	-0.216
innovative	-0.156	0.244	2.781	-0.153	3.082
fin_barr	-0.284	0.291*	-0.011	-0.046	0.016
hightech	3.882	-0.369	-3.692	0.059	-4.149
rev_prox	-0.014	0.021	0.153	0.054	0.089
_cons	2.674**	-2.111**	-11.339	-2.343*	-5.532
Predicted Prob.	0.8979	0.3297	0.0139	0.0613	0.0256
N	426				
Prob>Chi 2	0.3996				

+Multivariate Probit regression. Includes firms with R&D&i expenses in the 2007-2008 period*P. <0.05; **P.<0.01; ***P.<0.001

We also performed a regression for the subsample of innovative firms (Table 9). The results were quite similar, however, the bank access to innovative firms was slightly higher than the total sample. The probability for innovative firms to be funded by banks was 31.5% against 30% of the complete sample.

Table 9. MPR for innovative firms+

Variables	**internal**	**bank**	**equity**	**public**	**other sources**
randd	0.308***	0.053	-0.104	0.259*	0.14
biotech	-0.025	-0.117	0.206	-0.135	-0.312
intangible	0.355***	-0.008	0.271*	0.243*	0.106
tangible	-0.128	1.031***	-0.096	0.143	0.021
size	-0.021	0.065**	-0.02	0.166***	-0.016
foreign	0.163	-0.324***	-0.22	-0.155	0.154
innovative					
fin_barr	-0.105	0.242***	0.17	0.05	0.069

hightech	0.317	-0.420**	-0.31	0.093	-0.082
rev_prox	-0.028	0.022	0.064	-0.017	0.037
_cons	1.258***	-1.914***	-2.296***	-2.973***	-2.040***
Predicted Prob.	0.8771	0.3147	0.0208	0.0303	0.0313
N	2,413				
Prob>Chi 2	0.0000				

+Multivariate Probit regression. Includes firms with R&D&i expenses in the 2007-2008 period
*P. <0.05; **P.<0.01; ***P.<0.001

We executed the same multivariate probit regression in the case of firms using tangible and intangible assets. Our results are aligned with those found by Manigart & Struyf (1997), and can be seen in Table 10. In the case of firms with tangible assets, results for the independent variables were the same as in the case of the complete sample, however, the probability of bank access was slightly higher for firms expending in tangible assets with a 32% against 30% of the full sample. It seems that firms with more tangible assets, and therefore more collateral, could have more access to bank loans. In the case of intangible assets, the results showed that there was a higher probability for firms to use internal funds with a 92% against the 88% of the complete sample, or the 87% of the firms with tangible expenses.

Table 10. MPR. Firms with tangible and intangible assets expenses+

Firms with tangible assets expenses (tangible=1)					
Variables	**internal**	**bank**	**equity**	**Public**	**other sources**
randd	0.288**	0.037	-0.134	0.244*	0.177
biotech	-0.033	-0.087	0.218	-0.112	-0.277
intangible	0.344***	0.016	0.354**	0.245*	0.064
tangible					
size	-0.033	0.076**	-0.035	0.169***	-0.007
foreign	0.244	-0.330***	-0.361	-0.141	0.042
innovative	-0.017	0.497***	0.089	-0.158	-0.051
fin_barr	-0.109	0.233***	0.181	0.07	0.02
hightech	0.283	-0.343*	-0.261	0.011	-0.021
rev_prox	-0.029	0.02	0.06	-0.006	0.026
_cons	1.213***	-1.426***	-2.447***	-2.727***	-1.922***
Predicted Prob.	0.8749	0.3235	0.0201	0.0309	0.0311
N	2,388				
Prob>Chi 2	0.0000				
Firms with intangible assets expenses (intangible=1)					
	internal	**bank**	**equity**	**Public**	**other sources**
randd	0.243*	0.106	-0.254	0.261*	0.298*
biotech	-0.05	-0.035	0.303	-0.036	-0.305
intangible					
tangible	-0.176	1.078***	0.299	0.188	-0.143
size	-0.017	0.061	-0.07	0.112*	-0.086

foreign	0.117	-0.392**	-0.241	-0.026	0.231
innovative	0.217	0.390*	-0.245	-0.164	-0.026
fin_barr	-0.108	0.280***	0.119	0.028	0.16
hightech	0.291	-0.366	-0.201	0.042	-0.181
rev_prox	-0.061*	0.042*	0.147**	-0.003	0.066
_cons	1.576***	-2.448***	-2.119***	-2.388***	-1.675***
Predicted Prob.	0.9204	0.3016	0.0268	0.0430	0.0379
N	1,350				
Prob>Chi 2	0.0000				

+Multivariate Probit regression. Includes firms with R&D&i expenses in the 2007-2008 period
*P. <0.05; **P.<0.01; ***P.<0.001

Finally, we divided the sample between firms with higher and lower amounts of R&D expenses; in expenses; in this case, we used the log of the expense in R&D by employee to divide the sample in the sample in the above-average firms and below-average firms. The results can be seen in

Table 11. Firms with higher expenditure in R&D seemed to have a lower likelihood of using internal funds than in the complete sample. At the same time, the probability of those firms to use bank funding increased in large proportion with 41% against 30% of the complete sample.

Table 11. MPR. Firms above and below the R&D expenditure average+1.

Firms above the average of R&D expenditure					
Variables	***internal***	***bank***	***equity***	***public***	***other sources***
randd	0.348**	0.03	-0.311	0.14	0.029
biotech	0.02	-0.281**	0.088	-0.229	-0.319
intangible	0.471***	-0.182*	0.442*	0.227	-0.076
tangible	0.065	0.876***	0.034	0.051	-0.306
size	0.014	0.026	-0.072	0.155**	-0.087
foreign	0.152	-0.373***	-0.014	-0.153	0.199
innovative	-0.151	0.279	3.266	0.052	0.037
fin_barr	-0.195*	0.298***	0.023	0.102	0.05
hightech	0.336	-0.537**	-3.569	0.125	-0.034
rev_prox	-0.025	0.017	0.075	-0.015	0.02
_cons	0.903*	-1.493***	-5.435	-2.711***	-1.140*
Predicted Prob.	0.8529	0.4124	0.0213	0.0443	0.0408
N	1,375				
Prob>Chi 2	0.0000				
Firms below the average of R&D expenditure					
Variables	***internal***	***bank***	***equity***	***public***	***other sources***
randd	0.176	0.055	0.175	0.409*	0.392*

biotech	-0.039	-0.014	0.397	-0.137	-0.646
intangible	0.22	0.05	0.095	0.173	0.341
tangible	-0.19	0.771***	0.042	0.054	0.103
size	-0.113*	0.177***	0.054	0.176*	0.143
foreign	0.399	-0.499**	-3.348	-0.162	-0.267
innovative	0.064	0.421*	0.014	-0.353	-0.39
fin_barr	0.016	0.155	0.540*	-0.006	0.069
hightech	0.374	-0.165	0.067	0.093	-0.192
rev_prox	-0.019	0.022	0.088	-0.031	0.07
_cons	1.805***	-2.914***	-3.077***	-2.820***	-2.849***
Predicted Prob.	0.9104	0.1743	0.0202	0.0158	0.0219
N	1,246				
Prob>Chi 2	0.0000				

+Multivariate Probit regression. Includes firms with R&D&i expenses in the 2007-2008 period
*P. <0.05; **P.<0.01; ***P.<0.001
[1].R&D expenditure average was calculated for the log of the R&D expenditure by employee

In the case of firms with lower R&D expenses, we found that there is was 91% change for a firm using internal funds against 85% of higher R&D firms and 88% of the complete sample; this means firms with less R&D expenses tended to use more internal funding. At the same time firms with lower R&D expenses had a radically lower probability to use bank loans with 17% against the 41% of their counterparts, i.e., firms with lower amounts of R&D tended to use more internal funding and fewer bank loans.

In the case of Aghion, et al. (2004), and Minola & Cassia (2013), they found that the use of equity arises for firms with higher R&D, however, in our case, we cannot support that result. The probability of a firm to use equity was not affected by the amount of R&D used and had the lower probability of all the funding sources. As we posted before, a possible explanation for those differences could be due to the characteristics of capital markets in Colombia. In the case of Aghion, et al. (2004), Minola & Cassia (2013), and Audretsch & Lehmann (2004), the size and liquidity of the U.K., U.S., and German markets can give access to firms for equity funding, therefore, the possibility of firms to replace debt for equity when their ventures become larger or risky can arise. However, in underdeveloped countries, firms could be equity-constrained for capital market characteristics. Therefore, based on the late results, we can argue that in a country like Colombia innovative firms will tend to finance their innovation ventures in the same way that POT predicts, i.e., firms will be highly supported on internal funding. However, if internal funding is not enough to support ventures, firms have to have access to bank debt and in lower proportions to other types of funds like equity, public grants, and others, with equity being the funding source used least by firms.

3.5.Conclusions

Reviewed research about capital structure of innovative and high technology firms seems to be contradictory. Some of the research found that firms finance their R&D and innovation activities as described by the pecking order theory (POT), however, some others found evidence of an Altered Pecking Order Theory (APOT) structure. However, given that researches with evidence related to the APOT have been developed in countries like United Kingdom, the United States, and Germany, and in some cases with publicly traded firms, we confronted those results founded in a context of developed capital markets against an underdeveloped country with small and illiquid capital markets like Colombia.

We used the EDIT database for Colombia between 2007-2008 with 2.621 manufacturing firms with more than 10 employees and with positive R&D expenditures. Given that there were significate covariance's among the different types of sources used by these firms, we used a multivariate probit model to consider the simultaneity of the innovation funding phenomena.

Our results showed that type of expenditures in which firms use their funds are important to determine the financial sources used. Firms with internal funding are the ones expending on R&D and intangible assets. We believe that firms investing in that type of assets face higher information asymmetries and have lower capabilities to provide guarantees to use external funding. In the case of bank funding, the loan guarantees are fundamental to the access to debt. We argue this because we found positive and significant relationships between bank funding and expenditure on tangible assets.

In the case of public grants, an expenditure patron similar to the ones using internal sources were found, i.e., firms using public grants were the ones expending on R&D and intangible assets. We also found that intangible expenditures are related with equity funding, and it seems like firms with positive R&D and intangible expenditures supported their ventures by using internal, equity, and public funding.

Our results are aligned with literature showing that firm characteristics are determinant to the way innovative firms can have access to innovation funds (Ullah, et al., 2010; Bartolini, 2013; Hummel, et al, 2013; Minola & Cassia, 2013), however, this is not the case for internal funding — size, innovative behavior, or the perception of financial barriers, because they are not related with internal funding. Contrarily, the use of bank funding was strongly related with some firm characteristics. For instance, bigger firms and companies with a positive innovative behavior tended to have better access to bank funding; in the same direction, firms with a strong perception of financial barriers tended to use bank funding in higher proportions. As can be found in the literature, we related this late result to the fact that firms with higher perceptions of financial barriers had more experience in funding markets than other firms. At the same time, firms belonging to high technology industries seemed to be credit-constrained, i.e., there was a negative relationship between those industries and bank funding. We argue that market imperfections related to banks are stronger for firms in high technology industries. We also found that bigger firms are related to the use of public grants, and therefore the funding gap between SMEs and big firms is being accentuated for public funding.

We found that innovation ventures in Colombia follow a Pecking Order capital structure, i.e., firms are strongly using internal funds followed by banks, and then equity sources. However, the probability of firms using equity sources was lower than the probability of using government grants or other sources.

To understand how some particular groups of firms can have different probabilities of access to the financial sources, we studied the success probabilities for firms using one or another funding source. We found that no matter how the samples were divided, firms were following a pecking order capital structure; however, we found that the probabilities for the use of internal sources were higher when firms had lower R&D expenditures. Also, the probabilities for the use of bank funding were higher for those firms with upper R&D expenditures.

Our results can be contrasted with the Aghion, et al. (2004), Minola & Cassia (2013) and Audretsch & Lehmann (2004) research. Firms placed in countries like the United Kingdom, United States, or Germany, have higher access to equity funding given the

characteristics of capital markets in those countries, and therefore, the possibility of firms replacing the debt for equity when their ventures become larger or risky can arise. This because in order to successfully raise equity from markets, firms need to be supported by a liquid and specialized capital market to undertake an IPO, or to provide the necessary conditions for an exit strategy for an early venture capitalist (Hall & Lerner, 2010; Kerr & Nanda, 2015). However, in underdeveloped countries like Colombia, firms could be equity-constrained given that capital markets are in embryonic stages. Therefore, if internal funding is not enough to support ventures, firms have access to bank debt, and in lower proportions to other types of funding like equity or public grants.

These results have strong policy implications if innovative and high technology firms have problems financing their ventures, and in developed capital markets those firms have easier access to high risk equity and venture capital it is necessary for policy makers of underdeveloped countries to back up the expansion of strong and liquid capital markets in order to support the growth of innovative ventures and all the economic and social benefits related to those activities.

3.6.Bibliography

Aghion, P., Bond, S., Klemm, A., & Marinescu, I. (2004). Technology and financial structure: Are innovative firms different? *Journal of the European Economic Association*, 2, 277-288.

Arundel, A. (1997). Enterprise strategies and barriers to innovation. *Innovation Measurement and Policies*., Volume 50, 101-108.

Arundel, A., Bordoy, C., Mohnen, P., & Smith, K. H. (2008). Surveys and policy: lessons from the CIS.

Audretsch, D. B., & Lehmann, E. E. (2004). Financing High Tech Growth. *Schmalenbach Business Review*, 56, 340-357.

Baldwin, J., & Lin, Z. (2002). Impediments to advanced technology adoption for Canadian manufacturers. *Research policy*, 31(1), 1-18.

Bartolini, E. (2013). Capital structure and innovation: causality and determinants. *Empirica*, 40(1), 111-151.

Cappellari, L., & Jenkins, S. P. (2003). Multivariate probit regression using simulated maximum likelihood. *The Stata Journal*, 3(3), 278-294.

Colombo, M. G., & Grilli, L. (2007). Funding gaps? Access to bank loans by high-tech start-ups. *Small Business Economics*, 29(1-2), 25-46.

D'Este, P., Iammarino, S., Savona, M., & Von Tusselman, N. (2012). What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy*, 41(2), 482-488.

Freel, M. S. (2007). Are small innovators credit rationed? *Small Business Economics*, 28(1), 23-35.

Giudici, G., & Paleari, S. (2000). The provision of finance to innovation: A survey conducted among Italian Technology-based Small Firms. *Small Business Economics*, 14, 37-53.

Green, W. H. (2003). *Econometric Analysis.* Pearson Education India.

Hall, B. H., & Lerner, J. (2010). The financing of R&D and innovation. En B. H. Hall, & N. Rosenberg, *Handbook of the Economics of Innovation* (Vol. 1, págs. 609-639). Elsevier.

Hummel, D., Karcher, B., & Schultz, C. (2013). The financial structure of innovative SMEs in Germany. *Journal of Business Economics*, 83(5), 471-503.

Iammarino, S., Sanna Randaccio, F., & Savona, M. (2007). The perception of obstacles to innovation. Multinational and domestic firms in Italy. Office of Economic Theory and Application.

Kerr, W. R., & Nanda, R. (2015). Financing innovation. *Annual Review of Financial Economics*, 7, 445-462.

Kraus, A., & Litzemberg, R. H. (1973). A State-Preference Model of Optimal Financial Leverage. *The Journal of Finance*, 28(4), 911-922.

Manigart, S., & Struyf, C. (1997). Financing High Technology Startups. *Small Business Economics*, 9, 125-135.

Minola, T., & Cassia, L. (2013). Financing patterns in new technology-based firms: an extension of the pecking order theory. *International journal of entrepreneurship and small business*, 19(2), 212-233.

Modigliani, F., & Miller, M. H. (1958). The cost of capital, corporation finance and the theory of investment. *The American economic review*, 261-297.

Mortensen, P. S., & Bloch, C. W. (2005). Oslo Manual-Guidelines for collecting and interpreting innovation data. Organization for Economic Cooperation and Development, OECD.

Myers, S. C. (2001). Capital structure. *The Journal of Economic Perspectives*, 15(2), 81-102.

Myers, S. C., & Majluf, N. S. (1984). Corporate financing and investment decisions when firms have information that investors do not have. *Journal of financial economics*, 13(2), 187-221.

Sau, L. (2007). New pecking order financing for innovative firms: an overview. MPRA Working Papers (3659).

Schäfer, D., Werwatz, A., & Zimmermann, V. (2004). The determinants of debt and (private) equity financing: The case of young innovative SME's from Germany. *Industry and Innovation*, 11(3), 225-248.

Sierra, J., Malaver, F., & Vargas, M. (2009). La financiación de la innovación: un análisis a partir de la encuesta de innovación de Bogotá y Cundinamarca. *Encuestas, datos y descubrimiento de conocimiento sobre la innovación en Colombia*, 175-210.

Ullah, F., Abbas, Q., & Akbar, S. (2010). The relevance of pecking order hypothesis for the financing of computer software and biotechnology small firms: Some UK evidence. *International Entrepreneurship and Management Journal*, 6(3), 301-315.

Appendix A. High technology industries

Industry description	*ISIC Rev.3.1*	*Number of firms*
Manufacture of medical appliances and instruments and appliances for measuring, checking, testing, navigating and other purposes, except optical instruments	331	21
Manufacture of electric motors, generators and transformers	311	17
Manufacture of electricity distribution and control apparatus	312	16
Manufacture of other electrical equipment n.e.c.	319	12
Manufacture of electric lamps and lighting equipment	315	11
Manufacture of insulated wire and cable	313	5
Manufacture of accumulators, primary cells and primary batteries	314	5
Manufacture of electronic valves and tubes and other electronic components	321	2
Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods	323	2
Manufacture of optical instruments and photographic equipment	332	2
Manufacture of aircraft and spacecraft	353	2
Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy	322	1
Total		96 (3.7% of the sample)

Source: EDIT 2007-2008

Chapter 4. Where did the money go? Long-term input and output additionality of innovation subsidies in Spain

4.1.Introduction

In the last century, the concern of economists about the relationship among innovation, growth, and development has increased. Given that we now know that innovation activities create positive spillover effects on society, policy makers have a genuine interest in encouraging those types of activities around the world. However, innovation activities are risky and expensive, and sometimes private firms are not disposed to start those activities; in that sense, local and regional governments around the world design policies to spur innovation activities of private firms. Among those policies, one can find attractive tax regimens for firms investing in innovation, the promotion of innovation projects for public universities and laboratories, creation of scholarship programs to increase the number of researchers, and programs directed to private firms to diminish the risk and cost of undertaking innovation projects in the form of direct grants.

Given the rise of innovation surveys and methodologies focused on the determination of impacts of public policies, in recent years a growing number of researchers have been trying to understand the effects of innovation policies on firms' behavior, especially focusing on the impact of subsidies among firms; (i.e. if private firms do not engage in innovation because of market failures and it is possible to demonstrate that public subsidies generate positive, innovative behavior in private firms, those subsidies are simultaneously generating positive spillover effects on firms and society by diminishing market failures).

The majority of studies relating to subsidies and private firm innovation activities use non- structural models to measure those impacts (Cerulli, 2010). The use of this type of methodology is in part due to its relative simplicity compared with other methodologies

like structural models, in which it is necessary to determine the functional structure of a model of impact for subsidies to avoid some econometric issues like endogeneity.

In addition, most of studies have been focused on the possibility of the crowding-out or crowding-in effect of subsidies on private R&D (input additionality), neglecting that subsidies can have positive effects on other firm aspects. A small group of studies generally classify these other effects as output and behavioral additionalities. The former is generally measured by patents and revenues and the latter by cooperation and management variables related to innovative projects.

One of the biggest disadvantages of the literature reviewed for this research is the fact that in most of the cases, data comes from a cross section, which does not allow researchers to form conclusions about the effects of subsidy policies in the mid- and long-term or after the subsidy has been implemented. However, in the mid- and long-term, the additionality effects of subsidy could be more visible given the long-term nature of the innovation phenomena. This research is a small effort to understand the phenomena of subsidies to innovation and their input and output additionality effects in the long-term. We use a conditional difference in difference (CDID) approach given the long-term characteristics of innovation projects that in most cases cannot create impacts in a small period. We focus on two particular analyses of our data; first, we want to determine whether firm size is relevant in measuring additionality effects; therefore, we run separate models for SMEs and for large firms. In addition, we want to address whether a policy of reiterative grants makes firms prone to present higher additionality effects. Therefore, we also run separate regressions for firms receiving subsidies in at least two years in the study period against firms receiving subsidies in only a single year during the same period. This is novel research in the sense that this is the first time that long-term additionality effects will be addressed in Spain, and we are examining the effect of reiterative subsidies granted to firms on input and output additionalities.

Data used for this research comes from a yearly database panel for Spain firms for the years 2005 to 2013. The research is structured as follows: in the next section the literature related to the effects of subsidies on firm activities is discussed; in section 4.3, the data and methodology are presented. In section 4.4, the results of the econometric approach are debated, and in the final section, concluding remarks are presented.

4.2.Literature review

4.2.1. Issues with policy evaluation methodologies

Economists around the world agree that investment in research, development and innovation activities (R&D&i) generates positive spillover effects on society; to name just a few of those effects, one can bring up the raise in firm productivity, creation of new knowledge for firms developing R&D&I activities, and the effects of the new knowledge on markets, clients and competitors (David, et al., 2000).

In this direction, policy makers want to spur innovation inside firms, because of the positive effects created by those activities. However, there are some market failures that prevent firms from engaging in privately financed innovation projects. Positive effects of innovation can affect not only the innovator but its competitors also, and a firm in that case is expending valuable resources on activities that will benefit their competition; in other words, knowledge is a non-rival good and competitors can have access to that knowledge as free riders. In that sense, firms will not have incentives to engage in innovation activities because they are benefiting competitors. Moreover, innovation is costly and risky; therefore, some firms do not engage in innovation because the cost of finance innovation activities with external sources is higher compared with other types of ventures; simultaneously, risk of innovation arises because R&D&I activities are uncertain, i.e., innovation projects cannot guarantee the successful creation of a product or a service, because the high dependence of new knowledge creation on these projects (Arrow, 1962; Aerts & Czarnitzki, 2004; Hall & Lerner, 2010).

The above market failures tend to decrease the level of innovation projects to less than socially desired levels. Therefore, policy makers seek a way in which they can diminish the effect of failures. Among others, policies used to increase the level of innovation projects comprise *i)* tax incentives that reduce the cost of innovation activities and allow firms to choose the type of projects in which they want to engage and *ii*) subsidies to innovation that decrease the risk level of projects because the government provides firms with cash to develop their ideas of innovation, but do not allow firms to engage in

any type of innovation project, and therefore firms and projects financed are chosen by science and technology agencies (David, et al., 2000).

Given that public resources are scarce, researchers wonder about the effectiveness of government financed programs. If governments must choose among a great number of unmet needs like education, health, infrastructure, military, or innovation, how can they ensure that the chosen programs are appropriate to finance? Additionally, if governments decide to finance a determined policy, like innovation, how can they ensure that those programs are creating the expected effects?

What is sought by the empirical models for evaluation of public policies, and specifically in the case of subsidy policies for innovation, is to determine whether the companies receiving the subsidy show a more innovative performance than firms without subsidies, e.g., a researcher can evaluate whether the R&D expenditure levels are different for those groups; if this is true, it can be said that the subsidy is creating an effect in the R&D&I expenditure of those firms. In the literature, these types of effects are called input additionality, and they can be contrasted with the output and behavioral additionality effects of subsidies; the former are related to the level of innovation output which would not have been obtained without grants, and the latter is related to the way firms change their management and relationships after a grant (Autio, et al., 2008; Clarysse, et al., 2009; Bergman, et al., 2010).

Additionality comparisons have two fundamental issues; the first is that subsidies are not granted randomly (i.e., public agencies determine if firms should be "awarded" or not with subsidies). For additionality analysis, this is a problem because firms awarded with subsidies have dissimilar characteristics compared with non-subsidized firms, e.g., if the agency tries to maximize the social benefits of grants, will be interested in the selection of firms, or innovation projects, that make the best use of those resources, and the agency will adopt a "picking the winner" strategy (Aerts & Czarnitzki, 2004). Generally, those winner firms are the ones with R&D&I laboratories, patent applications, higher levels of R&D expenditure, and other characteristics related to the successful accomplishment of innovation projects. Given that there is a non-random criterion in the provision of subsidies and that innovation input and output levels of those firms are different before grants, a simple statistic strategy of mean differences

between the innovation inputs and outputs of firms, with and without subsidies, is not appropriate and could drive researchers to conclude that subsidies are the cause of differences that were present even before the grant (Cerulli & Potí, 2008).

The second problem arises from the last one; given that a simple mean comparison is not appropriate, it is necessary to develop a set of empirical strategies to evaluate the subsidy policy. Generally, two sets of methodologies can be found, structural and non-structural. For the first group, it is necessary to determine the functional form of the empirical model; for example, if a model correlates the R&D expenditure against the subsidy as an explanatory variable, the error term and subsidy would be correlated and would cause inconsistent estimations given that agencies do not select granted firms randomly (Busom, 2000; Almus & Czartnitzki, 2003; Cerulli, 2010). A way to solve these problems is to include all the variables used by government agencies to select subsidized firms as control variables. However, if some of the variables remain unobservable another strategy is needed.

Another way to solve this issue is the use of instrumental variables (IV) in which a system of equations is developed to extract the subsidy variable from the original equation; the subsidy is then related with some IVs to determine their statistical relationship with two stages less square (2SLS) or three stages less square (3SLS) strategies. If the IVs are exogenous to the error term, then the results of the system are not biased. The issue with this type of model is that it can be difficult to determine the IV to use and probe the exogenous nature of that variable with the original equation error term. Studies using these methodologies can be found in Wallsten (2000), Busom (2000), Gelabert, et.al. (2009), Cerulli (2010) and García & Mohnen (2010).

On the other hand, the non-parametric methodologies are the most used in the field of innovation to solve the randomness issue; this type of methodology tries to answer one simple question: What would a subsidized firm do without the subsidies? If there are some effects of the grant policies, the comparison of a single firm with and without the subsidies can show the effects caused by a subsidy on that company. However, the comparison of these effects is not possible because an observer can only perceive one of those states of the firm (i.e., states are mutually exclusive). The last is recognized in the literature as the counterfactual issue; a researcher cannot observe in each moment of

time a firm with and without the subsidy, so the answer to the question raised before must be addressed differently (Heckman, et al., 1999).

One way to solve the counterfactual issue is to select a control group to compare with subsidized firms. To do this, it is possible to identify a set of firms similar in all aspects with granted firms except for the grant received; this methodology is called the parametric matching procedure. The idea behind this method is to reestablish the conditions of an experiment when no randomized control group is available (Chudnovsky, et al., 2006). The perfect case of a matching procedure would include as many characteristics as the ones used to determine subsidy grants; however, the bigger the characteristics vector, the lower the likelihood of find a match between the subsidized and control groups (Görg & Strobl, 2007).

The two stages propensity matching score methodology tries to solve this issue. This procedure was developed by Rubin (1977), and it has been used in most of the studies evaluating subsidies to innovation with cross-sectional data. The procedure considers the counterfactual issue, and therefore, compares a firm with a subsidy against a "twin" firm without the subsidy, but instead of a vector of characteristics uses the likelihood of a firm to receive subsidies, thereby reducing the matching issue to only one characteristic, called the propensity score. In the first stage of this procedure, generally, a probit model is developed to match firms with similar propensity scores depending on a set of firm characteristics, and in the second stage the matched firms are compared to determine the additional effects of subsidies. The rationality behind this methodology is that if grant likelihoods before a grant were similar, the post-grant differences among firms' characteristics must be due to the subsidy.

The two stages matching procedure is a powerful tool to evaluate the effect of subsidies. However, has a major drawback; it only allows one to control for a firm's observable heterogeneity among control and granted firms, i.e., some unobserved characteristics are still present during the matching procedure, and these characteristics could make firms react differently when external shocks arise.

The difference in difference (DID) methodology tries to control for the lack of observable differences among firms and the counterfactual issue comparing firms

receiving subsidies before and after the grant, then, comparing those changes against the changes of firms not receiving subsidies before and after the treatment period.

The rationality behind the DID methodology is that differences in behavior can be observed in the periods before and after treatment and inside treated and not treated groups. However, the drawbacks are that it needs a panel or repeated cross section data to be developed and does not control for observed heterogeneity among firms. To solve the latter issue, a combination of parametric matching and DID procedures can be done; this procedure is called the conditional difference in difference (CDID) estimation and it was first proposed by Blundell & Dias (2002). In this procedure, the counterfactual is addressed by using a propensity score matching in the period before the subsidy was granted, which is expected to identify firms with a similar likelihood of being granted even before the subsidy occurs. Generally, this procedure is done by means of a probit model. Once the matching procedure is done, a DID methodology is applied to the firms in the control group before and after the subsidy and with treated firms before and after the procedure. If the differences between the control group and the treated group after the treatment period are significant, then the subsidy is creating an effect on treated firms. This methodology controls for counterfactual and observed heterogeneity with the matching procedure and for the unobserved and time-invariant characteristics with the DID procedure. Therefore, the final results of the CDID methodology are unbiased (Blundell & Dias, 2002; Aerts & Schmidt, 2008).

4.2.2. Evaluation of innovation subsidy policies in practice

Given that innovation is a long-term endeavor, public policy evaluation must be developed with a long-term perspective. However, it is hard to find panel data on innovation to perform such analysis. In the case of Community Innovation Surveys (CIS) for Europe, few studies have been developed, and in most of the cases, a cross section analysis has been performed using parametric and non-parametric methodologies.

Among the papers in which innovation subsidies policies has been evaluated, a central question has arisen: Does the granting of subsidies create a crowding out effect on firms' private R&D expenditure (i.e. there is a substitution or a complementary effect of the subsidies on the firm expenditure on R&D)? In terms of policy, the question is

relevant given that firms can react to subsidies in multiple ways. If government policies, as discussed earlier, seek to grant subsidies to firms with higher success likelihood on innovation projects, it is possible that the subsidy displace private R&D expenditure and the firm will probably expend the same amount of R&D with or without the grant because the innovation project promises positive outcomes in the near future. However, if a firm elevates the level of private R&D after the subsidy, a crowding in effect will arise; this could happen when firms perceive the subsidy as a complement of their own effort (Aerts & Czarnitzki, 2004).

The great majority of the studies about innovation subsidies using the propensity score matching methodology, find that there is a crowding in or a complementary effect on private R&D (Busom, 2000; Almus & Czartnitzki, 2003; Heijs & Herrera, 2004; Aerts & Czarnitzki, 2004; Lööf & Heshmati, 2005; Czarnitzki et al., 2007; González & Pazó, 2008; Aerts & Schmidt, 2008; Cerulli & Potí, 2008; Czarnitzki & Lopes-Bento, 2012; Czarnitzki & Lopes-Bento, 2013; Czarnitzki & Lopes-Bento, 2014).

As it was posited before, innovation creates positive spillover or additionality effects on society, like elevation of markets productivity, effects of new knowledge on markets, clients and competitors, new jobs, higher levels of exportations, cooperation agreements and so on (Klette, et al., 2000); for that reason, it is logical to think that innovation subsidies also create another type of positive spillover or additionality effect on firms. However, just a few group of researchers have focused on other type of variable, different from the question about substitution and complementarity between public and private expenditure.

In the case of behavioral additionalities, Autio et. al. (2008) using a sample of 66 Finland companies between 1998 and 2002, finds that second order additionalities (behavioral additionalities) like technological learning, market learning and internationalization learning are boosted by innovation grants. Clarysse et. al. (2009) using Flanders data, finds a strong relationship among government grants, formalization of innovation processes, innovation management capabilities, and firms research paths. Wanzenböck et.al. (2013) using Austria's transport sector data, discovers that project desertion likelihood is smaller after a grant and that cooperation and knowledge transfer rise after innovation grants.

In the case of output additionalities, Wallsten (2000), using a parametric approach, wonders if subsidy grants create an effect on employment in the U.S. firms and finds that there are no effects on total employment, additionaly, finding that there is a substitution effect of the subsidies against private R&D expenditure. Czarnitzki et al. (2007) using the Community Innovation Surveys (CIS) from Germany and Finland, suggests that firms without subsidies would generate fewer patents than firms with subsidies. García & Mohnen (2010) investigate the effect of subsidies on output additionality, measured by the share of revenues due to innovation; they use the CIS for Austria and discover that firms with subsidies to innovation increase their new to the market revenues by 3.4%. Czarnitzki & Lopes-Bento (2013), estimate the effect of public subsidies on employment level for the north region of Belgium and discover that there is a positive effect of subsidies on R&D employees. Czarnitzki & Lopes-Bento (2014) wonder if subsidy grants have effects on innovative revenues and patent behavior in Germany; they find that subsidies have a positive effect on both output measures. Except for Wallsten (2000), consulted studies find that there is a positive effect of innovation subsidies on input, behavioral and output additionalities, and therefore, there is empirical evidence of positive spillover effects of innovation subsidies.

Further, even when there is genuine concern about other spillover effects of innovation subsidies on firms, there is little evidence about the mid and long-term effects of innovation subsidies on firms; this is caused by the cross-sectional nature of most data used by the mentioned studies that mostly uses one wave of innovation surveys. Nevertheless, there are some exceptions; Lach (2002) uses a DID procedure with panel data from Israel to determine if there is a positive effect of subsidies on R&D behavior on small and large firms. Lach found that subsidies create a positive effect in the long-term for small firms, but cannot demonstrate that the same happens with large firms. Using the same methodology, Sanguinetti (2005) found that Argentinian firms between 1992 and 2001 have a crowding in effect on internal R&D after subsidies. However, he finds no effects on total R&D expenditure. Czarnitzki & Lopes-Bento (2013) wonder if treatment effects are stable over time and uses data from Belgium for 2004, 2006 and 2008, with three separate parametric matching procedures, and concludes that the effects of subsidies are stable over time. (i.e., there is no evidence of a decline of the

additionally effects of subsidies policy over time). Czarnitzki & Lopes-Bento (2013) also discusses the effects of multiple subsidies on firms and finds that there is no declining effect on input additionality for those firms.

In the case of CDID methodology, Görg & Strobl (2007) using data from Ireland firms throughout the years 1999-2002, conclude that there is an additionality effect on R&D expenditure in the case of small or medium size subsidies. However, there is a replacement effect in the case of large subsidies. Aerts & Schmidt (2008) using Germany and Flanders data for CIS III and CIS IV waves, concludes that there is an additionality effect on R&D after subsidies; as part of the conclusion of this research they suggest studing the output effects of grants by using the same methodology as we are approaching on this research. A CDID case worth highlighting is the Chudnovsky et. al. (2006) research; in this paper, 1998-2004 data of Argentinian firms is used, and the research concludes that subsidies spur private R&D expenditure but have no long-term effects on productivity or new to the market product revenues. As far as we know, this is the only case when a CDID methodology has been used to study the additionality output effects of innovation grants.

This is novel research in the sense that this is the first time that long-term additionality effects will be addressed in Spain and because we are researching the effect of reiterative subsidies granted to firms on input and output additionalities.

4.3.Empirical Approach

4.3.1. Methodology

In this research, a methodology CDID is used. This procedure combines a parametric matching approach whit a DID methodology. We want to determinate whether firms receiving subsidies have input and output additionality effects in the long-term and if there are any differences on additionality of firms receiving recurrent subsidies. The rationality behind this methodology can be described as follows.

Suppose that each firm *i* has two potential states, Y_{i1} (subsidized or treated firm) or Y_{i0} (not subsidized or control firm). The effect of subsidy could be calculated by $E(Y_{i1} - Y_{i0})$. However, Y_{i0} cannot be observed and is a counterfactual (i.e. a firm cannot have both states, subsidized and not subsidized at the same time). Therefore, a parallel approach has to be done to measure an average effect of subsidies.

We can define *Di* as a dichotomous indicator of grants with a value of one representing a firm receiving subsidies and zero otherwise. Therefore, the average treatment effect on the treated (ATET) could be calculated as:

$$ATET = E(Y_{i1}|D_i = 1) - E(Y_{i0}|D_i = 1)$$

However, $E(Y_{i0}|D_i = 1)$ is also a counterfactual that cannot be observed because it measures the outcome *Y* of a not subsidized firm in the case of been subsidized; therefore, this parameter must be estimated. If conditional independence between subsidies and outcome variables could be assumed, a set of observable characteristics *X* used to select granted firms could be used in order to determine the outcomes of non-treated (control) firms. Therefore, it can be said that:

$$E(Y_{i0}|X_i, D_i = 1) = E(Y_{i0}|X_i, D_i = 0)$$

However, not all the characteristics that should be included in X_i are observable or available, and the more variables included on firms' characteristics vector, the more difficult it would be to find a match among treated and not treated firms. According to Rubin (1977) and Rosenbaum & Rubin (1983), this problem can be overcome by reducing the firm characteristics vector to a single index, the propensity score, that accounts for the likelihood of a firm to receive a subsidy. In that case:

$$P(D_i = 1) = F(X_i)$$

It is possible to determine X_i using a cumulative standard normal distribution function by means of a probit model, and in that case, the propensity score measures the likelihood of a firm receiving a subsidy. This propensity score is used to match treated and not treated firms and the comparison of those groups of firms could be calculated by:

$$ATET = E(Y_{i1}|X_i, D_i = 1) - E(Y_{i0}|X_i, D_i = 0)$$

Given that we want to determine the long-term effects of subsidies and we are using panel data to do so, we extend the last equation to compare the effects of subsidies on time using a DID methodology:

$$ATET_t = E\big(Y_{i1t}|X_{it-1}, D_{it} = 1,\ D_{it-1} = 0) - E(Y_{i0t}|X_{it-1}, D_{it} = 0,\ D_{it-1} = 0)\big)$$

This is a combination of a DID methodology with a previous propensity score matching procedure; this is called CDID methodology and it was proposed by Blundell & Dias (2002). This methodology controls for counterfactual and observed heterogeneity with the matching procedure and for the unobserved and time invariant characteristics with the DID procedure. Therefore, the final results of the CDID methodology are unbiased (Aerts & Schmidt, 2008). For this research, we use the procedure of CDID developed by Villa (2016).

4.3.2. Data

The data used in this research comes from the PITEC[8] database for the years 2005 to 2013. Our sample consists of firms not receiving any kind of public subsidy during 2005 and 2007[9] to control for any effects caused by subsidies in later years. Within this sample, it is possible to find two types of companies, those not receiving any subsidies during the period 2008-2013 (this will be our control group) and firms receiving subsidies at least once during the same period (this will be our treated group). The baseline period will be 2007, and the treatment years will be 2008-2013 with 2013 being our follow-up period. We want to determine the long-term effects of receiving subsidies to innovation, therefore, separation of these sub-samples has as its main objective to evaluate the long-term effect comparing 2007 against 2013. In addition, we control our sample for firms with positive internal R&D expenditure, and we reduce our sample to 1559 firms.

As we noted previously, the procedure that we use to control for the counterfactual is a propensity matching score, in this case, that matching is performed with data of the sample for the 2007 period. The variables used to run the probit regression previous to the matching are the log of number of employees (lnsize), a dummy variable controlling

[8] Technologic Innovation Panel, for its acronym in Spanish
[9] For the year 2006 PITEC has no data about received subsidies on firms.

the firm group belonging (group), a dummy variable controlling for foreign origin (foreign), a dummy variable counting the fact that firms sell their products mainly in countries outside the European Union (nonue_exp), a dummy controlling for firms perceiving strong financial impediments on their innovation activities (barfin) and two dummies controlling for high technology manufacture and services industries firms (htmanuf; htserv)[10].

Following the Villa (2016) methodology, after the probit model a kernel propensity score matching was developed using an Epanechnikov kernel function; this allows us to have control and treated groups of firms in which the observed heterogeneity is no longer an issue (i.e. the main characteristics of firms before the subsidy are controlled and now the only difference between groups is that some companies will receive innovation grants in the future). Therefore, any differences in outcome variables on the follow-up years must be the effect of those subsidies; the results of this matching procedure are presented on Appendix B.

After the matching, the DID procedure compares the mean outcome variable of the control group in the baseline year (2007) against the mean outcome variable in the follow-up year (2013). This is the long-term difference in outcome for control firms. In addition, this procedure is repeated for treated firms, this is, the long-term difference in outcome for treated companies. Given that with matching procedure we control for firm observed characteristics, the comparison of long-term differences of control and treated firms (DID) is the ATET of subsidies on outcome variables and it is also controlled by the invariant and unobserved firm characteristics.

As effect outcomes, we use two separate sets of variables (Table 12). The first group is a set of input variables measuring the effects on internal and external R&D expenditure or intensity and the number of employees working on R&D activities. The second group is a set of output variables measuring total revenues and new to the market revenues. We use these variables as outputs because the fact that firms increase their revenues as a result of innovation subsidies means that grants have direct effects on the potential expansion of firms and markets.

[10] For simplicity, the results of the probit models used to perform the matching procedure are not presented. These results can be made available on request.

Table 12. Input and output outcome variables

Type of outcome	***Outcome variable description***	***Outcome variable name***
Input	Logarithm of internal R&D expenditure	rd_ln
	Logarithm of internal R&D expenditure by employee (Internal R&D/ total employees)	emprd_ln
	Logarithm of internal R&D intensity (Internal R&D/ revenues)	intensity
	Logarithm of number of employees working on R&D	ln_idsize
	Logarithm of R&D employees' proportion (R&D employees / Total Employees)	ln_idprop
	Logarithm of external R&D expenditure	exrd_ln
	Logarithm of external R&D expenditure by employee (External R&D/ total employees)	empexrd_ln
	Logarithm of external R&D intensity (External R&D/ revenues)	ex_intensity
Output	Logarithm of Revenues	rev_ln
	Logarithm of Revenues by employee (Revenues/ total employees)	emrev_ln
	Logarithm of new to the market total revenues	nmarket_ln
	Logarithm of new to the market total revenues by employee (new market sales / total employees)	nmarket_em

We would also like to measure the effects on behavior outcomes (cooperation, abandonment of projects, etc.), but we cannot find on PITEC survey any behavior-related variables measured as continuous variables; the issue with this is that our methodology uses a linear regression to perform the CDID effects (Villa, 2016) and, therefore, using non-continuous variables to measure behavioral additionalities would result in biased parameters. Moreover, the fact that a linear regression is used plays in our favor also; given that as is shown in Table 12, all our variables are measured on logarithms, the CDID effects could be interpreted as a percentage change among control and treated firms caused by subsidies after we transform the results by an exponential function[11].

In addition, we want to understand whether the long-term effect of the subsidies affects SME's and large firms differently, because SMEs tend to deal with strong market failures preventing them from performing innovation activities. Therefore, we expect that additionality effects would be bigger for SMEs than for large firms. To account for those facts, we first perform CDID models for all firms; then we separate our analysis of SMEs and large firms.

[11] Exp[ATET]-1

Lastly, we perform a separate analysis for firms receiving recurrent subsidies during the period 2008-2013; as can be seen in Table 13, 63.7% of firms (334/524) have received more than one grant during the period 2008-2013, These 334 firms will be our treated group in the last regression, to understand whether firms with recurrent subsidies present any differences from the complete treated group.

Table 13. Sample Description

Number of grants	**All sample**	**SME's**	**Large Firms**
0 (control group)	1035	856	179
1	190	155	35
2	134	116	18
3	75	58	17
4	64	50	14
5	36	24	12
6	25	20	5
Treated	**524**	**423**	**101**
Total	**1559**	**1279**	**280**

Lastly, we perform robustness checks combining firm size and recurrence grants DID to determine whether there are any differences among the full sample and the SMEs and large firms' subsamples. As can be seen in Table 13, 63,4% and 65.3% of SMEs and large firms receive recurrent subsidies in the 2008-2013 period.

4.4. Results

4.4.1. Effects on the full sample

Table 14 shows the results of the CDID analysis for the full sample of firms receiving subsidies for at least one year. At first glance, the estimations for the baseline, follow-up periods, and the DID shows that a crowding out effect can be discarded; after an exponential transformation of these results it can be said that compared with control firms, companies receiving subsidies expend 31% more on internal R&D, have 24% more internal R&D expenditures per employee, and have 24% more R&D intensity in 2013 than in 2007. Consequently, there is an additionality effect of grants over internal R&D.

Further, the effects on external R&D additionality are significant. Firms granted expend 66% more on external R&D, and 58% more on external R&D per employee, and have

58% more intensity of external R&D. Given that the effects of external R&D almost double those of the internal R&D expenditures, it can be said that treated firms privilege the increase of knowledge external acquisition over knowledge internal formation; in line with Cohen & Levinthal (1990), acquisition of external knowledge is a way to spur internal R&D that generates absorptive capacities. Therefore, it is expected that firms acquiring more external R&D have better long-term capacities to develop internal knowledge, appropriate external technologies, and to participate in cooperative ventures.

Table 14. CDID. Firms receiving at least one subsidy in 2008 – 2013. Full Sample.

Additionality variables		***Baseline*** **2007** ***Diff (T-C) [1]***	***Follow-up*** **2013** ***Diff (T-C) [2]***	***Diff in Diff [2- 1] (Exponential Transformation[1])***
Input	rd_ln	0.218***	0.487***	0.269** (31%)
	emprd_ln	0.173***	0.386***	0.213** (24%)
	intensity	0.254***	0.469***	0.215* (24%)
	exrd_ln	0.598***	1.107***	0.509*** (66%)
	empexrd_ln	0.552***	1.006***	0.453*** (57%)
	ex_intensity	0.633***	1.089***	0.456*** (58%)
	ln_idsize	0.185***	0.362***	0.178*** (19%)
	ln_idprop	0.181***	0.337***	0.156* (17%)
Output	rev_ln	-0,036	0,018	0,054
	emrev_ln	-0.081*	-0,058	0,022
	nmarket_ln	0,056	0,198	0,142
	nmarket_em	-0,011	-0,095	-0,083
***P. Value<0.01; **P. Value<0.05; *P. Value<0.1				

Sample: Firms with no subsidies in period 2005 - 2007 and positive internal R&D expenditures
Treated (T): Firms receiving at least one subsidy in period 2008-2013
Control (C): Firms with no subsidies in period 2008–2013
[1.] EXP(DID)-1, presented only for significant models.

The results exposed in Table 14 show that in the long-term firms elevates by 19% the number of R&D employees and by 17% the proportion of R&D employees. This is important given that firms need workers with strong individual absorptive capacities in order to develop new knowledge and to develop innovation skills within the firm; in addition, policy-makers are interested in spurring high knowledge workers in order to generate more innovation spillovers in markets when those workers go to other firms or generate new start-ups.

Further, the results presented in Table 14 show that there are no long-term output additionality effects, at least for the total, by employee and new to the market revenues. These findings are related to the ones of Chudnovsky et. al. (2006). It seems like grants have no long-term effects on sales, productivity or new to the market revenues for

Spanish firms. The fact that we found input but not output additionalities, could give an important message to policy-makers and researchers in order to identify those output variables prone to vary during the follow-up period. Perhaps it is necessary to focus on another kind of output outcomes, like patents or behavior additionality, to test potential spillover effects of grants. However, in our case, the fact that linear regressions were used to determine the CDID results did not allow us to use any of the binary or count behavior and outcome variables funded on PITEC to test that hypothesis.

4.4.1. Effects on SMEs and large firms

In Table 15 the results for the subsamples of SMEs and large firms are presented. In the first place, it is important to mention that there are numerous input additionality effects for SMEs, whereas in large firms the CDID models were not significant. For SMEs, the crowding out hypothesis can be rejected given that firms receiving at least one subsidy expend 36% more on internal R&D than control firms and expend 19% more on internal R&D per employee. Even when the intensity of internal R&D is not significant, there are sufficient hints to conclude that there is an additionality effect of grants on SMEs' internal R&D expenditure.

External R&D expenditure follows the same patterns as the full sample, i.e. the effects are bigger than those of internal R&D expenditure in a range from 44% of external R&D per employee to 64% of total external R&D expenditure showing that after subsidies, SMEs also privilege the increase of knowledge external acquisition over knowledge internal formation.

Table 15. CDID for firms receiving at least one subsidy in period 2008–2013.

Additionality variables		***SMEs DID (Exponential Transformation[1])***	***Large firms DID (Exponential Transformation[1])***
Input	rd_ln	0.305*** (36%)	0.131
	emprd_ln	0.176* (19%)	0.339
	intensity	0,205	0.206
	exrd_ln	0.496*** (64%)	0.511
	empexrd_ln	0.368** (44%)	0.719
	ex_intensity	0.397** (49%)	0.586
	ln_idsize	0.183*** (20%)	0.075
	ln_idprop	0.096	0.295
Output	rev_ln	0.099	-0.075
	emrev_ln	0.001	0.133
	nmarket_ln	0.067	0.477
	nmarket_em	-0.302	0.534

***P. Value<0.01; **P. Value<0.05; *P. Value<0.1
Sample: Firms with no subsidies in the period 2005-2007 and positive internal R&D expenditures.
Treated (T): Firms receiving at least one subsidy in period 2008-2013

Control (C): Firms with no subsidies in period 2008-2013
[1.] EXP(DID)-1, presented only for significant models.

The number of R&D employees has positive outcomes also, granted SMEs tend to have 20% more R&D linked workers. The fact that the proportion of R&D employees (ln-idprop) has no significant effects could show that smaller firms increase the number of total and R&D employees at a similar rate.

As was seen for the full sample, there are no outcome additionality effects for SMEs and large firms. Additionally, there are no effects of any kind for larger firms as can be seen in Table 15; our results are aligned with those of Lach (2002). The fact that larger firms show no additionality input and output effects could be an important message for policy-makers; even when there are no crowding out or backward input and output effects for large firms, it seems like smaller firms tend to take better advantage of subsidies.

4.4.2. Single vs. recurrent subsidies

Results for firms receiving single and multiple grants for the period 2008-2013 are presented in Table 16 and Table 17, respectively. Firms receiving a single grant (Table 16) seems to have fewer additionality effects than those receiving them on a recurrent basis. Single granted firms have additionality effects only on external R&D expenditures; those effects vary from 37% for external R&D intensity to 46% for total external R&D expenditure. Small firms tend to expend 21% more on internal R&D, and therefore, it is possible to discard a crowding out effect for those firms. However, for large firms and the complete set of firms this crowding out effect cannot be rejected. It seems like the concession of single grants tends to elevate the internal and external R&D expenditure of SMEs, but it has no effects on R&D employees or output variables. Like the previous models, large firms tend to show no additionality effects when a single subsidy is granted to them.

Table 16. CDID for firms receiving subsidies in a single year

Additionality variables		***All Firms DID (Exponential Transformation[1])***	***SMEs DID (Exponential Transformation[1])***	***Large Firms DID (Exponential Transformation[1])***
Input	rd_ln	0.164	0.193* (21%)	-0.055
	emprd_ln	0.168	0.141	0.282
	intensity	0.101	0.110	0.101
	exrd_ln	0.376*** (46%)	0.380** (46%)	0.111
	empexrd_ln	0.380** (46%)	0.328* (39%)	0.448
	ex_intensity	0.313* (37%)	0.297	0.267

	ln_idsize	0.053	0.065	-0.127
	ln_idprop	0.075	0.036	0.199
Output	rev_ln	0.062	0.083	-0.156
	emrev_ln	0.067	0.031	0.181
	nmarket_ln	0.154	0.055	0.406
	nmarket_em	0.024	-0.170	0.519
***P. Value<0.01; **P. Value<0.05; *P. Value<0.1				

Sample: Firms with no subsidies in the period 2005-2007 and positive internal R&D expenditures.
Treated (T): Firms receiving at least one subsidy in period 2008-2013.
Control (C): Firms with no subsidies in period 2008–2013.
[1.] EXP(DID)-1, presented only for significant models.

Results for firms receiving subsidies for multiple years are shown in Table 17. Those firms have several additionality input effects for the complete set of firms, SMEs, and for large firms. The complete set of firms has positive additionality effects on internal and external expenditures on R&D and in the recruiting and proportion of R&D related employees; interestingly, a comparison of results of Table 14 and Table 17 shows that the additionality effects on multiple granted firms (all firms and SMEs) are bigger than those of the full sample. These results show that policy-makers may be interested in innovation policies where firms, especially SMEs, participate in a long-time innovation aid program rather than being granted with sporadic subsidies.

Table 17. CDID for firms receiving subsidies for multiple years

Additionality variables		***All Firms DID (Exponential Transformation[1])***	***SMEs DID (Exponential Transformation[1])***	***Large Firms DID (Exponential Transformation[1])***
Input	rd_ln	0.329*** (39%)	0.370*** (45%)	0.252
	emprd_ln	0.241** (27%)	0.198* (22%)	0.398
	intensity	0.286** (33%)	0.261* (30%)	0.314
	exrd_ln	0.589*** (80%)	0.564*** (76%)	0.714
	empexrd_ln	0.501*** (65%)	0.392** (48%)	0.860* (136%)
	ex_intensity	0.546*** (73%)	0.455** (58%)	0.776* (117%)
	ln_idsize	0.249*** (28%)	0.252*** (29%)	0.205
	ln_idprop	0.206** (23%)	0.132	0.376
Output	rev_ln	0.043	0.109	-0.063
	emrev_ln	-0.007	-0.015	0.084
	nmarket_ln	0.137	0.078	0.466
	nmarket_em	-0.181	-0.374	0.596

***P. Value<0.01; **P. Value<0.05; *P. Value<0.1
Sample: Firms with no subsidies in period the 2005-2007 and positive internal R&D expenditures.
Treated (T): Firms receiving grants on multiple years among 2008-2013.
Control (C): Firms with no subsidies in period 2008–2013.
[1.] EXP(DID)-1, presented only for significant models.

Contrary to what was observed with the other models, large firms receiving recurrent grants tend to have positive additionality effects. However, these effects are related only with external R&D expenditure and therefore, the crowding out effect for large firms cannot be discarded. Interestingly, additionality effects for external R&D expenditure in

large firms are the largest of all performed regressions. External R&D expenditure per employee and external R&D intensity are 136% and 117% larger than control firms in the baseline year; following the Cohen & Levinthal (1990) thesis, those firms could be generating absorptive capacities in order to develop internal knowledge in the future. However, since it is difficult to believe that these types of companies had not developed those capacities previously, our interpretation is that large firms use recurrent grants simply to buy machinery, contract turnkey projects, and buy other forms of external knowledge. In this sense, if grants public policies are designed to elevate internal firm capacities to create future spillovers, a recurrent innovation subsidy policy for large firms could be misleading.

4.5. Conclusions

In this research, a CDID methodology was used to determine whether Spanish firms receiving innovation grants during 2008-2013 present significant input and output additionality effects.

Our results are aligned with the previous literature, (Busom, 2000; Almus & Czartnitzki, 2003; Heijs & Herrera, 2004; Aerts & Czarnitzki, 2004; Lööf & Heshmati, 2005; Czarnitzki, et al., 2007; González & Pazó, 2008; Aerts & Schmidt, 2008; Cerulli & Potí, 2008; Czarnitzki & Lopes-Bento, 2012; Czarnitzki & Lopes-Bento, 2013; Czarnitzki & Lopes-Bento, 2014) given that we found that there are no crowding out effects of innovation subsidies. However, this result could only be found for SMEs but not in the case of large firms, as it was found by Lach (2002).

In all cases, external R&D expenditures additionality effects were bigger than internal R&D effects and therefore, we conclude that grants are a fundamental part of a firm's absorptive capacities improvement (Cohen & Levinthal, 1990), at least for SMEs; in addition, SMEs tend to increase R&D employees' recruitment in number and proportion when compared with the control group in the baseline years. No output effects were found in any of the subsamples used and our findings are aligned with those of Chudnovsky et. al. (2006). However, the use of CDID methodology does not allow us to use count or dummy output variables to test the robustness of these results. When the results of recurrence in subsidies are observed, firms receiving recurrent grants in the

2008-2013 period tend to show more and larger additionality effects than firms receiving single grants.

Our results generate important messages for policy makers. First, SMEs tend to have greater input and output additionality effects than large firms. Consequently, innovation subsidy policies have to be directed mostly to this kind of firms, which, as found in the literature, are the companies confronting higher market barriers performing innovation (Iammarino, et.al., 2007; Madrid-Guijarro, et.al, 2009). Second, the fact that outcome additionality cannot be found require for policy-makers and researchers to find adequate variables to measure the long-term effect of innovation subsidies and their spillovers. Third, depending on the policy focus, it could be a good move to develop long-time innovation aid programs rather than sporadic grants for firms. Though large firms are usually the ones with adequate capacities for yearly projects to be granted, and they present fewer additionality effects, those long-term policies should be directed to small firms with high growth potential because it is through these companies that subsidies could generate more long-term innovative spillovers for society.

4.6. Bibliography

Aerts, K. & Czarnitzki, D., 2004. Using innovation survey data to evaluate R&D policy: The case of Belgium. ZEW-Centre for European Economic Research Discussion Paper, pp. 04-055.

Aerts, K. & Schmidt, T., 2008. Two for the price of one? Additionality effects of R&D subsidies: A comparison between Flanders and Germany. *Research Policy*, 37(5), pp. 806-822.

Almus, M. & Czartnitzki, D., 2003. The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany. *Journal of Business & Economic Statistics*, 21(2), pp. 226-236.

Arrow, K., 1962. Economic welfare and the allocation of resources for invention. In: *The Rate of Inventive Activity: Economic and Social Factors*. Princeton: Princeton University Press.

Autio, E., Kanninen, S. & Gustafsson, R., 2008. First- and second-order additionality and learning outcomes in collaborative R&D programs. *Research Policy*, 37(1), pp. 59-76.

Bergman, K. et al., 2010. Bergman, K., Ejermo, O., Fischer, J., Hallonsten, O., Hansen, Effects of VINNOVA Programmes on Small and Medium-sized Enterprises-the cases of Forska&Väx and VINN NU, s.l.: Sweden Links.

Blundell, R. & Dias, M., 2002. Alternative approaches to evaluation in empirical microeconomics. *Portuguese economic journal*, 1(2), pp. 91-115.

Busom, I., 2000. An empirical evaluation of the effects of R&D subsidies. *Economics of innovation and new technology*, 9(2), pp. 111-148.

Cerulli, G., 2010. Modelling and measuring the effect of public subsidies on business R&D: a critical review of the econometric literature. *Economic Record*, 86(274), pp. 421-449.

Cerulli, G. & Potí, B., 2008. Evaluating the Effect of Public Subsidies of Firm R&D Activity: An Application to Italy Using the Community Innovation Survey. CERIS-CNR, Working Paper N°9(Anno 10).

Chudnovsky, D., López, A., Rossi, M. & Ubfal, D., 2006. Evaluating a program of public funding of private innovation activities: An econometric study of FONTAR in Argentina, Washington: Inter-American Development Bank.

Clarysse, B., Wright, M. & Mustar, P., 2009. Behavioural additionality of R&D subsidies: A learning perspective. *Research Policy*, 38(10), pp. 1517-1533.

Cohen, W. M. & Levinthal, D. A., 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, pp. 128-152.

Czarnitzki, D., Ebersberger, B. & Fier, A., 2007. The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany. *Journal of applied econometrics*, 22(7), pp. 1347-1366.

Czarnitzki, D. & Lopes-Bento, C., 2012. Evaluation of public R&D policies: A cross-country comparison. *World Review of Science, Technology and Sustainable Development*, 9(2-4), pp. 254-282.

Czarnitzki, D. & Lopes-Bento, C., 2013. Value for money? New microeconometric evidence on public R&D grants in Flanders. *Research Policy*, 42(1), pp. 76-89.

Czarnitzki, D. & Lopes-Bento, C., 2014. Innovation subsidies: Does the funding source matter for innovation intensity and performance? Empirical evidence from Germany. *Industry and Innovation*, 21(5), pp. 380-409.

David, P. A., Hall, B. H. & Toole, A. A., 2000. Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Research Policy*, 29(4), pp. 497-529.

García, A. & Mohnen, P., 2010. Impact of government support on R&D and innovation.

Gelabert, L., Fosfuri, A. & Tribó, J. A., 2009. Does the effect of public support for R&D depend on the degree of appropriability? *The Journal of Industrial Economics*, 57(4), pp. 736-767.

González, X. & Pazó, C., 2008. Do public subsidies stimulate private R&D spending? *Research Policy*, 37(3), pp. 371-389.

Görg, H. & Strobl, E., 2007. The effect of R&D subsidies on private R&D. *Economica*, 74(294), pp. 215-234.

Hall, B. & Lerner, J., 2010. The financing of R&D and innovation. In: *Handbook of the Economics of Innovation*. s.l.:s.n., pp. 609-639.

Heckman, J. J., LaLonde, R. J. & Smith, J. A., 1999. The economics and econometrics of active labor market programs. In: *Handbook of labor economics*. s.l.:s.n., pp. 1865-2097.

Heijs, J. & Herrera, D. L., 2004. The distribution of R&D subsidies and its effect on the final outcome of innovation policy.

Iammarino, S., Sanna, R. & Savona, M., 2007. The perception of obstacles to innovation. Multinational and domestic firms in Italy. Office of Economic Theory and Application.

Klette, T. J., Møen, J. & Griliches, Z., 2000. Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies. *Research Policy*, 29(4), pp. 471-495.

Lach, S., 2002. Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel. *The journal of industrial economics*, 50(4), pp. 369-390.

Lööf, H. & Heshmati, A., 2005. The impact of public funds on private R&D investment: New evidence from a firm level innovation study. MTT Discussion Papers, Volume 3, pp. 1-26.

Madrid-Guijarro, A., García, D. & Van Auken, H., 2009. Barriers to innovation among Spanish manufacturing SMEs. *Journal of Small Business Management*, 47(4), pp. 465-488.

Rosenbaum, P. & Rubin, D. B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika*, pp. 41-55.

Rubin, D., 1977. Assignment to Treatment Group on the Basis of a Covariate. *Journal of Educational and Behavioral statistics*, pp. 1-26.

Sanguinetti, P., 2005. Innovation and R&D expenditures in Argentina: evidence from a firm level survey, Buenos Aires: Universidad Torcuato Di Tella, Department of Economics, Buenos Aires.

Villa, J. M., 2016. DIFF: Stata module to perform Differences in Differences estimation. Statistical Software Components.

Wallsten, S. J., 2000. The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research program. *The RAND Journal of Economics*, pp. 82-100.

Wanzenböck, I., Scherngell, T. & Fischer, M., 2013. How do firm characteristics affect behavioural additionalities of public R&D subsidies? Evidence for the Austrian transport sector. *Technovation*, 33(2-3), pp. 66-77.

Appendix B. Matching Procedure

Firms receiving subsidies at least for one year						
Variables	***All firms***		***SME's***		***Large Firms***	
	Before Matching	***After Matching***	***Before Matching***	***After Matching***	***Before Matching***	***After Matching***
	Diff. (T-C)	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***
lnsize	-0.082	0.045	-0.026	0.004	-0.289**	0.022
group	-0.014	0.005	-0.003	0.012	-0.051	-0.009
foreign	0	-0.002	0.022	-0.009	-0.084	-0.012
nonue_exp	0.053**	-0.017	0.044	-0.008	0.09	-0.018
barfin	-0.022	0.003	-0.016	-0.002	-0.045	0.022
htmanuf	0.01	0.005	0.014	0.008	-0.008	-0.014
htserv	-0.048***	0.006	-0.049**	0.013	-0.042	-0.003

***P. Value<0.01; **P. Value<0.05; *P. Value<0.1

Firms receiving subsidies only for one year						
Variables	***All firms***		***SME's***		***Large Firms***	
	Before Matching	***After Matching***	***Before Matching***	***After Matching***	***Before Matching***	***After Matching***
	Diff. (T-C)	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***
lnsize	-0.033	0.064	-0,096	0,019	-0,028	-0,019
group	-0.026	0.026	-0,014	0,005	-0.135**	0,001
foreign	-0.004	0	0,018	-0,012	-0.143*	0,001
nonue_exp	0.053	-0.003	0,054	-0,017	0,042	-0,032
barfin	0.002	-0.007	0,007	-0,008	-0,001	0,027
htmanuf	0.01	-0.002	0,025	0,005	-0,060	0,041
htserv	-0.057**	0.01	-0.061**	0,023	-0,035	-0,002

***P.Value<0.01; **P. Value<0.05; *P. Value<0.1

Firms receiving subsidies for more than one year						
Variables	***All firms***		***SME's***		***Large Firms***	
	Before Matching	***After Matching***	***Before Matching***	***After Matching***	***Before Matching***	***After Matching***
	Diff. (T-C)	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***	***Diff. (T-C)***
lnsize	-0.109	0.046	0,016	-0,008	-0.414**	0,036
group	-0.006	0.002	0,003	0,018	-0,011	-0,01
foreign	0.003	0,000	0,024	-0,004	-0,056	0,003
nonue_exp	0.053*	-0.015	0,038	-0,014	0.113*	-0,003
barfin	-0.035	0.013	-0,030	0,013	-0,066	0,018
htmanuf	0.009	0.001	0,008	-0,001	0,017	-0,014
htserv	-0.042**	0.009	-0.042*	0,024	-0,046	-0,012

***P. Value<0.01; **P. Value<0.05; *P. Value<0.1

Chapter 5. Concluding remarks and policy implications

One way to make evident the market and National Systems of Innovation (NSI) deficiencies confronted by innovative firms and countries, is via the differences in R&D expenditures posted in Chapter 1; private business R&D investment tends to be lower in less developed countries. Therefore, one of the main goals of governments and academics should be the implementation of a set of policies and institutions focused on the increase of private business expenditure on R&D, especially in underdeveloped countries, to generate long-term development.

Neo-Schumpeterian and evolutionary economic traditions have researched this phenomenon since the beginning, and some policy effects are visible now; for example, all over the world the concept of NSI has been adopted by policy-makers in order to understand differences between markets' innovative performance and the ways in which those systems could support firms and organizations to overcome innovation impediments (Edquist, 2010). However, we are far from a full understanding of the effects of market failures on firms' innovative activities and from the design of a set of policies and institutions arranged to overcome those failures. In that sense, this dissertation deals with the phenomenon of market failures affecting innovation activities and the financial sources of SME innovative firms in Spain and Colombia. The main idea behind this thesis was to answer the research question: what are the financing sources and innovative particularities of small innovative firms facing innovation impediments?

In the second chapter, using data for Spanish SME firms from 2003 and 2013, it was shown that perception of innovation impediments is strong in SMEs; those firms tend to fail in their innovative ventures via a diverse set of barriers, like economic/financial, knowledge, and market impediments. However, until now, no attention was paid to the complete process of innovation related to this perception, and the literature tends to ignore the fact that firms become involved in innovation to profit from it and focuses only on the invention stage where there is still a long path to innovation.

In that sense, a separation of invention and commercialization stages was made in order to determine whether there are differences in the perception of innovation impediments in those stages. The results show that firms tend to perceive knowledge and economic/financial barriers in the invention stage. However, the commercialization stage is characterized by the perception of market impediments (i.e. those related with competition and uncertainty). Firms successfully completing innovation process (i.e. selling innovative products and services) have no perception of impediments; ergo, firms profiting from innovation ventures are those overcoming market failures.

The management implications of those results are strong. First, firms in the invention phase need to ensure the arrival of financing funds in order to overcome successfully that stage of the innovation process and therefore, profit from innovation in the near future (Chapter 3 and Chapter 4 deals with that implication looking at the way firms fund their innovation ventures through private sources and the effect of public funding innovation within firms). At the same time, firms should solve their high knowledge workers vacuum to perform well in the invention phase, this is, they need specialized personal capable of fully understand the complex implications of innovation ventures. Given that firms with an invention tend to perceive competition and uncertainty (market impediments) as major drawbacks, those firms should be prepared to compete with consolidated firms with more experience and resources if they want to survive in markets. At the same time, those firms might reduce uncertainty using well-established methodologies like technological and competitive intelligence or forecasting by prospective analysis.

The policy implications of those results are also strong; the fact that firms on the commercialization stage tend to perceive only market impediments shows that government decision makers could develop better-suited policies in order to diminish market failures related un unfair competition and unregulated monopolies. At the same time, the fact that firms already profiting from innovation tend to perceive no impediments shows that governments can develop policies aimed to reduce all type of market failures if they want a complete set of innovation spillovers impacting markets. At the same time, policy-makers might enforce the creation and development of organizations and institutions related to the generation of high-knowledge workers to

support firms in the invention phase (i.e. strength of the education system as a way to support firms to overcome innovation impediments).

In Chapter 3, using data from Colombia, it was found that small firms tend to have lower access to bank and equity funding to back up their innovation ventures. Therefore, these types of firms tend to use internal funds and government subsidies to finance those activities. At the same time, firms expending their R&D on tangible assets tend to have more access to bank loans. Consequently, firms with high intangible asset generation in their innovation processes have lower probabilities of being financed.

The Chapter 3 results can also be contrasted with literature backing a hypothesis of Altered Pecking Order given that Colombian firms, no matter which type, follow a Pecking Order capital structure to finance their innovative ventures; it was proposed that these results are the consequence of an underdeveloped financial market that shortens the likelihood of firms using equity as a source of funds for innovation. In this regard, government-backed funds are more likely than equity funds in Colombia to perform innovation. This is disturbing given that government agencies related to science, technology and innovation, specifically in Colombia, have lower budgets to subsidize private firms in the country, and given the fact that tax exemptions for R&D projects have been granted to big firms in high proportions in the past decades (79%) (Departamento Nacional de Planeación, 2015). In that sense, SMEs in Colombia use cash flow because those firms have no access to other funding sources for innovation ventures. Thus, the results of total R&D expenditures posted in Figure 1 and Figure 2 could have a relationship with the development of Colombia's financial system and with the short stock of backed up financial aids from Colombia´s government.

There are other implications of the Chapter 3 results; from the management point of view, the fact that intangible assets have a negative relationship with the access to external capital is an opportunity for firms and financial institutions to develop a relationship based on harmonized systematic reports displaying the stock of intellectual capital of SMEs. Some efforts about this topic have been developed in recent years, especially with the emergence of the Intellectual Capital Statement made in Europe (InCas), which is a report that seeks to systematize embedded knowledge within organizations as a source of information for strategic management and to reduce

information asymmetries with funding institutions and investors (Mertins & Will, 2007; Sánchez, et al., 2012). If those kinds of methodologies arise, it is possible that access to external funding for SMEs could be less restricted. However, in Colombia as far as is known, there are still no efforts to implement this type of methodology.

The Policy implications are also interesting. Given that SMEs are the ones confronting more difficulties in accessing external capital for innovative ventures, governments could develop strategies in order to ease the access to that capital, especially in countries like Colombia where the public budget for R&D has been shortening in recent years. Thus, the development of SME exchange markets could be a medium-term policy to give firms access to that long-term capital. In that sense, the KOSDAQ market created in 1996 in Korea, TSX venture created in Canada in 1999, and Alternative Investment Market (AIM) created in 1995 in London are the paradigms to follow (World Federation of Exchanges, 2016). In order to allow the creation of such markets, it is necessary for governments to make more flexible regulation for SMEs to access Initial Public Offerings (IPOs), and to back up the creation of those kinds of markets into the existing regulated ones; at the same time, the creation of a policy to report on intellectual capital for those firms, as it was posted in the last paragraph, could be useful to diminish agency cost for equity capital in those markets. From the theory point of view, this is related with the Edquist (2010) proposal to strengthen NSI by the development of a better organizational and institutional framework to finance innovation.

At the same time, access to external capital is constricted in relation with banks; the literature reviewed and the results of the empirical models of Chapter 2 support the idea that financial cost of innovation is higher in relation to other types of investments, so a possible policy that governments around the world could use to partially overcome this issue is the development of an interest rate subsidy for innovative projects. In many economies around the world, interest mortgage subsidy is a policy to improve access to homeownership as a way to provide positive spillovers to the economy. The practical way to implement that subsidy is to cover one to four percentage points of mortgage interest rates for households. Given that innovation creates spillovers in markets also, a policy to reduce the interest rates faced by the innovative firm in banking markets could elevate the private expenditure in R&D and innovation and their spillovers in economy.

The fact that SMEs confront several market failures and that those firms need to overcome those failures to effectively profit from innovation (Chapter 2), but at the same time, SMEs tend to be restricted to access external sources of funds (Chapter 3), leads one to think that a government strategy to grant subsidies to SMEs could be a good approach. In relation with the last idea and using data about Spanish firms for the 2005-2013 period, in Chapter 4 research about the impact of subsidies in long-term input and output performance was presented. The results of this research show that SMEs present no crowding out effect for R&D internal expenditures. Moreover, there is a complementary effect of subsidies. At the same time, absorptive capacities improvement, measured as an impact on external R&D expenditure, has positive increments after subsidy grants. In the same direction, R&D employees' recruitment rises in the long-term after subsidies; however, output effects on innovation performance could not be proved. Simultaneously, in Chapter 4 it was shown that the recurrence of subsidies increases the effect on input additionality, therefore, firms receiving subsidies in sporadic years tend to be less impacted than firms receiving grants in recurrent years.

The management implications of those results are appealing; given that knowledge impediments are important in the invention phase of firms (Chapter 2), the fact that subsidies in the long-term tend to increase the capacity of firms to contract R&D employees could lead firms to apply for subsidies to overcome not only economic/financial impediments, but knowledge impediments, too. At the same time, given that absorptive capacities of firms tend to be expanded over the years, especially if firms receive recurrent subsidies, firms less experienced in developing their own innovation projects might apply for grants in order to acquire external R&D; in the long-term, that could generate internal and external spillovers for firms, their peers, and society (i.e., a "not picking the winner" strategy could in some sense, diminish the lack of innovation capabilities within firms).

Concurrently, those results could be a stimulus for firms looking to develop their innovation projects through cooperation agreements with clients, peers, universities, and government institutions. If the acquisition of external knowledge could expand their capabilities to develop innovation, the open innovation framework proposed by

Chesbrough (2003), as a way to share knowledge, could also be a form to overcome market failures confronted by SMEs; in this sense, policies aimed at the implementation of cooperation policies between national and international companies like the Horizon 2020 – international co-operation program should be implemented all over the world.

Under the same line of thought, there are other results in Chapter 4 that are interesting from the policy point of view. First, the fact that outcome additionality could not be proved with variables used in this research, and that the literature has found various difficulties in the measure of those outcome improvements, could lead to the search for new and better outcome variables to include in innovation surveys around the world. At the same time, this could lead to shift the attention of policy makers and academics towards behavioral variables more suited to evaluate the innovation subsidy policies or new methodologies to explain those effects.

Likewise, the fact that additionality effects are greater for SMEs than for large firms emphasizes the idea that innovation subsidy policies could be focused on firms confronting innovation impediments in higher proportions, like recently created small firms, unlike what happens in Colombia. Last, but not least, a policy focused on long-term innovation aid programs could generate more economic impact than sporadic subsidies granted to firms. However, policy-makers might be aware of the types of firms granted with these type of policies, given that large firms are better suited to present and be awarded with innovation grants.

Finally, all three chapters composing this dissertation expose a number of research lines that could be developed in the future, beginning with Chapter 2, it would be interesting to determine which policy and management instruments are valid to fully overcome impediments of firms on invention and appropriation stages of the innovation process especially, knowledge and market impediments that at difference of economic/financial impediments have been less studied in the past. In that sense, the open innovation framework seems to be promising.

Chapter 3 opens a complete set of new research questions to be answered in the near future. First, if financial markets are so important for innovation ventures, what was the impact of the 2008 financial crisis on the flow of innovation around the world? At the

same time, even when there are some studies concluding that there is a relationship between financial markets' sophistication and innovation, more attention needs to be paid to the underdeveloped countries in which those markets are less developed. In this regard, research on the impact that small business stock exchanges of London, Toronto, and Korea have had on innovation outcomes at the regional level, and the optimal ways in which those kinds of markets could be implemented in underdeveloped countries, should be developed from the financial and NSI points of view.

In addition, a research agenda proposed by European studies related to the implementation of intellectual capital reports in order to diminish the information asymmetry with investors could be put into practice in underdeveloped countries. In the short-term, implementing the study cases of firms and banks disposed to use this kind of information and in the long-run proposing the development of a government-backed implementation exercise in a country like Colombia.

For Chapter 4, the implementation of studies measuring the long-term additionality of innovation grants for behavioral variables like willingness to innovate, co-operation, open innovation readiness, abandonment of innovation projects, and others could be a good starting point to find another type of additionality effect of innovation from the microeconomic point of view.

Finally, the great attention displayed in recent decades about the relationship of innovation and economic development, draws attention to developing more and profound efforts to maximize the levels of private R&D investments, government policies, and academic research related to the innovation framework. Those efforts will be conducted in the long-term not only to increase economic development but to decrease social inequalities.

5.1.Complete bibliography

Aerts, K. & Czarnitzki, D., 2004. Using innovation survey data to evaluate R&D policy: The case of Belgium. ZEW-Centre for European Economic Research Discussion Paper, pp. 04-055.

Aerts, K. & Schmidt, T., 2008. Two for the price of one? Additionality effects of R&D subsidies: A comparison between Flanders and Germany. *Research Policy*, 37(5), pp. 806-822.

Aghion, P., Bond, S., Klemm, A. & Marinescu, I., 2004. Technology and financial structure: Are innovative firms different? *Journal of the European Economic Association*, Volume 2, pp. 277-288.

Almus, M. & Czartnitzki, D., 2003. The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany. *Journal of Business & Economic Statistics*, 21(2), pp. 226-236.

Arrow, K., 1962. Economic welfare and the allocation of resources for invention. En: T. R. Corporation, ed. In *The rate and direction of inventive activity: Economic and social factors*. Boston: Princeton University Press, pp. 606-626.

Arundel, A., 1997. Enterprise strategies and barriers to innovation. *Innovation Measurement and Policies.*, Volume 50, pp. 101-108.

Arundel, A., Bordoy, C., Mohnen, P. & Smith, K. H., 2008. Surveys and policy: lessons from the CIS.

Arundel, A. & Smith, K., 2013. History of the community innovation survey. En: F. Gault, ed. *Handbook of Innovation Indicators and Measurement*. s.l.:Edward Elgar Publishing, pp. 60-87.

Audretsch, D. B. & Lehmann, E. E., 2004. Financing High Tech Growth. Schmalenbach *Business Review*, Volume 56, pp. 340-357.

Autio, E., Kanninen, S. & Gustafsson, R., 2008. First- and second-order additionality and learning outcomes in collaborative R&D programs. *Research Policy*, 37(1), pp. 59-76.

Baldwin, J. & Lin, Z., 2002. Impediments to advanced technology adoption for Canadian manufacturers. *Research policy*, 31(1), pp. 1-18.

Bartolini, E., 2013. Capital structure and innovation: causality and determinants. *Empirica*, 40(1), pp. 111-151.

Bergman, K., Ejermo, O., Fischer, J., Hallonsten, O., Hansen, Effects of VINNOVA Programs on Small and Medium-sized Enterprises-the cases of Forska&Väx and VINN NU, s.l.: Sweden Links.

Blundell, R. & Dias, M., 2002. Alternative approaches to evaluation in empirical microeconomics. *Portuguese economic journal*, 1(2), pp. 91-115.

Blanchard, P., Huiban, J. P., Musolesi, A. & Sevestre, P., 2013. Where there is a will, there is a way? Assessing the impact of obstacles to innovation. *Industrial and Corporate Change*, 22(3), pp. 679-710.

Brown, J. R., Fazzari, S. M. & Petersen, B. C., 2009. Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom. *The Journal of Finance*, 64(1), pp. 151-185.

Busom, I., 2000. An empirical evaluation of the effects of R&D subsidies. *Economics of innovation and new technology*, 9(2), pp. 111-148.

Canepa, A. & Stoneman, P., 2002. Financial constraints on innovation: A European cross-country study. Kiel Institute of World Economics, Working Paper, pp. 2-11.

Castellacci, F., 2008. Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation. *Research Policy*, 37(6), pp. 978-994.

Cappellari. L. & Jenkins, S. P., 2003. Multivariate probit regression using simulated maximum likelihood. *The Stata Journal*, 3(3), pp. 278-294.

Cerulli, G., 2010. Modelling and measuring the effect of public subsidies on business R&D: a critical review of the econometric literature. *Economic Record*, 86(274), pp. 421-449.

Cerulli, G. & Potí, B., 2008. Evaluating the Effect of Public Subsidies of Firm R&D Activity: An Application to Italy Using the Community Innovation Survey. CERIS-CNR, Working Paper N°9(Anno 10).

Chesbrough, H., 2003. The Logic of Open Innovation: Managing Intellectual Property. *California Management Review*, 45(3), pp. 33-58.

Chesbrough, H. W., 2006. *Open innovation: The new imperative for creating and profiting from technology*. 12 ed. Boston, MA, USA: Harvard Business Press.

Chudnovsky, D., López, A., Rossi, M. & Ubfal, D., 2006. Evaluating a program of public funding of private innovation activities: An econometric study of FONTAR in Argentina, Washington: Inter-American Development Bank.

Clarysse, B., Wright, M. & Mustar, P., 2009. Behavioral additionality of R&D subsidies: A learning perspective. *Research Policy*, 38(10), pp. 1517-1533.

Cohen, W. M. & Levinthal, D. A., 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, pp. 128-152.

Colombo, M. G. & Grilli, L., 2007. Funding gaps? Access to bank loans by high-tech start-ups. *Small Business Economics*, 29(1-2), pp. 25-46.

Czarnitzki, D., Ebersberger, B. & Fier, A., 2007. The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany. *Journal of applied econometrics*, 22(7), pp. 1347-1366.

Czarnitzki, D. & Lopes-Bento, C., 2012. Evaluation of public R&D policies: A cross-country comparison. *World Review of Science, Technology and Sustainable Development*, 9(2-4), pp. 254-282.

Czarnitzki, D. & Lopes-Bento, C., 2013. Value for money? New micro-econometric evidence on public R&D grants in Flanders. *Research Policy*, 42(1), pp. 76-89.

Czarnitzki, D. & Lopes-Bento, C., 2014. Innovation subsidies: Does the funding source matter for innovation intensity and performance? Empirical evidence from Germany. *Industry and Innovation*, 21(5), pp. 380-409.

David, P. A., Hall, B. H. & Toole, A. A., 2000. Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Research Policy*, 29(4), pp. 497-529.

De Sabios, I., 1996. *Informe de la misión de sabios. Colombia: al filo de la oportunidad, Bogotá*: Tercer Mundo Editores.

Departamento Nacional de Planeación, 2015. Lineamientos de política para estimular la inversión privada en ciencia, tecnología e innovación a través de deducciones tributarias (CONPES 3834), Bogotá: DNP.

D'Este, P., Iammarino, S., Savona, M. & Von Tusselman, N., 2012. What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy*, 41(2), pp. 482-488.

Edquist, C. 2010. Systems of innovation perspectives and challenges. *African Journal of Science, Technology, Innovation and Development*, 2(3), 14-45.

Freel, M. S., 2007. Are small innovators credit rationed? *Small Business Economics*, 28(1), pp. 23-35.

Freeman, C. 1987. *Technology policy and economic performance: Lessons from Japan*, London: Pinter.

García, A. & Mohnen, P., 2010. Impact of government support on R&D and innovation.

García-Vega, M. & López, A., 2010. Determinants of abandoning innovative activities: evidence from Spanish Firms. *Cuadernos de economía y dirección de empresa*, 13(45), pp. 69-91.

Galia, F. & Legros, D., 2004. Complementarities between obstacles to innovation: evidence from France. *Research policy*, 33(8), pp. 1185-1199.

Gelabert, L., Fosfuri, A. & Tribó, J. A., 2009. Does the effect of public support for R&D depend on the degree of appropriability? *The Journal of Industrial Economics*, 57(4), pp. 736-767.

Giudici, G. & Paleari, S., 2000. The provision of finance to innovation: A survey conducted among Italian Technology-based Small Firms. *Small Business Economics*, Volume 14, pp. 37-53.

González, X. & Pazó, C., 2008. Do public subsidies stimulate private R&D spending? *Research Policy*, 37(3), pp. 371-389.

Görg, H. & Strobl, E., 2007. The effect of R&D subsidies on private R&D. *Economica*, 74(294), pp. 215-234.

Green, W. H., 2003. *Econometric Analysis*. s.l.:Pearson Education India.

Griliches, Z., 1988. Productivity Puzzles and R & D: Another Non-explanation. The *Journal of Economic Perspectives*, 2(4), pp. 9-21.

Hall, B. H. & Lerner, J., 2010. The financing of R&D and innovation. In: *Handbook of the Economics of Innovation*. s.l.:s.n., pp. 609-639.

Heckman, J. J., LaLonde, R. J. & Smith, J. A., 1999. The economics and econometrics of active labor market programs. In: *Handbook of labor economics*. s.l.:s.n., pp. 1865-2097.

Heijs, J. & Herrera, D. L., 2004. The distribution of R&D subsidies and its effect on the final outcome of innovation policy.

Henttonen, K., Ojanen, V. & Puumalainen, K., 2015. Searching for appropriate performance measures for innovation and development projects. *R&D Management*.

Hummel, D., Karcher, B. & Schultz, C., 2013. The financial structure of innovative SMEs in Germany. *Journal of Business Economics*, 83(5), pp. 471-503.

Hurmelinna- Laukkanen, P. & Puumalainen, K., 2007. Nature and dynamics of appropriability: strategies for appropriating returns on innovation. *R&D Management*, 37(2), pp. 95-112.

Iammarino, S., Sanna Randaccio, F. & Savona, M., 2007. The perception of obstacles to innovation. Multinational and domestic firms in Italy. Office of Economic Theory and Application.

Kerr, W. R. & Nanda, R., 2015. Financing innovation. *Annual Review of Financial Economics*, Volume 7, pp. 445-462.

Klette, T. J., Møen, J. & Griliches, Z., 2000. Do subsidies to commercial R&D reduce market failures? Micro-econometric evaluation studies. *Research Policy*, 29(4), pp. 471-495.

Kraus, A. & Litzemberg, R. H., 1973. A State-Preference Model of Optimal Financial Leverage. *The Journal of Finance*, 28(4), pp. 911-922.

Lach, S., 2002. Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel. *The journal of industrial economics*, 50(4), pp. 369-390.

Lööf, H. & Heshmati, A., 2005. The impact of public funds on private R&D investment: New evidence from a firm level innovation study. MTT Discussion Papers, Volumen 3, pp. 1-26.

Lundvall, B. 1992. *National systems of innovation: Towards a theory of innovation and interactive learning*, London: Pinter.

Madrid-Guijarro, A., García, D. & Van Auken, H., 2009. Barriers to innovation among Spanish manufacturing SMEs. *Journal of Small Business Management*, 47(4), pp. 465-488.

Manigart, S. & Struyf, C., 1997. Financing High Technology Startups. *Small Business Economics*, Volume 9, pp. 125-135.

Mertins, K. & Will, M., 2007. A Consistent Assessment of Intellectual Capital in SMEs InCaS: Intellectual Capital Statement--Made in Europe. *Electronic Journal of Knowledge Management*, 5(4).

Minola, T. & Cassia, L., 2013. Financing patterns in new technology-based firms: an extension of the pecking order theory. *International journal of entrepreneurship and small business*, 19(2), pp. 212-233.

Modigliani, F. & Miller, M. H., 1958. The cost of capital, corporation finance and the theory of investment. *The American economic review*, pp. 261-297.

Mohnen, P., Palm, F., Van Der Loeff, S. & Tiwari, A., 2008. Financial constraints and other obstacles: are they a threat to innovation activity? *De Economist*, 156(2), pp. 201-214.

Mohnen, P. & Rosa, J., 2001. Les obstacles a l'innovation dans les industries de services au Canada. L' actulité économique, 77(2), pp. 231-254.

Mortensen, P. S. & Bloch, C. W., 2005. Oslo Manual-Guidelines for collecting and interpreting innovation data, s.l.: Organization for Economic Cooperation and Development, OECD.

Myers, S. C., 2001. Capital structure. *The Journal of Economic Perspectives*, 15(2), pp. 81-102.

Myers, S. C. & Majluf, N. S., 1984. Corporate financing and investment decisions when firms have information that investors do not have. *Journal of financial economics*, 13(2), pp. 187-221.

Nelson, R., 1959. The simple economics of basic scientific research. *Journal of political economy*, 67(3), pp. 297-306.

Nelson, R. R. 1993. *National systems of innovation: A comparative study*, Oxford: Oxford University Press.

Nelson, R. R. & Winter, S. G., 1982. *An evolutionary theory of economic change*. Harvard Business School Press.

OECD, 1997. The measurement of scientific and technological activities: proposed guidelines for collecting and interpreting technological innovation data: Oslo manual. 1 ed. Oslo: Organization for Economic Co-operation and Development.

Pellegrino, G. & Savona, M., 2013. Is money all? Financing versus Knowledge and Demand Constraints to Innovation. UNI-MERIT Working Paper Series, Volume 29.

Pérez-Cano, C., 2013. Firm size and appropriability of the results of innovation. *Journal of Engineering and Technology Management*, 30(3), pp. 209-226.

Rosenbaum, P. & Rubin, D. B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika*, pp. 41-55.

Rubin, D., 1977. Assignment to Treatment Group on the Basis of a Covariate. *Journal of Educational and Behavioral statistics*, pp. 1-26.

Salazar, M. & Holbrook, A., 2004. A debate on innovation surveys. *Science and public policy*, 31(4), p. 254.

Sánchez, M. P., Salazar, J. C. & Basilio, O., 2012. Intellectual Capital Management as Support for Financing Innovation in SMEs. Helsinki, Academic Conferences Limited, p. 403.

Sanguinetti, P., 2005. Innovation and R&D expenditures in Argentina: evidence from a firm level survey, Buenos Aires: Universidad Torcuato Di Tella, Department of Economics, Buenos Aires.

Sau, L., 2007. New pecking order financing for innovative firms: an overview. MPRA Working Papers, Issue 3659.

Savignac, F., 2008. Impact of financial constraints on innovation: what can be learned from a direct measure? *Econ. Innov. New Techn.*, 17(6), pp. 553-569.

Schäfer, D., Werwatz, A. & Zimmermann, V., 2004. The determinants of debt and (private) equity financing: The case of young innovative SME's from Germany. *Industry and Innovation*, 11(3), pp. 225-248.

Schumpeter, J. A., 1939. *Business Cycles: a theorical, historical, and statistical analysis of the capitalist process*. 1 ed. New York (New York State): Harper and Brothers.

Segarra-Blasco, A., García-Quevedo, J. & Teruel-Carrizosa, M., 2008. Barriers to innovation and public policy in Catalonia. *International entrepreneurship and management journal*, 4(4), pp. 431-451.

Sierra, J., Malaver, F. & Vargas, M., 2009. La financiación de la innovación: un análisis a partir de la encuesta de innovación de Bogotá y Cundinamarca. *Encuestas, datos y descubrimiento de conocimiento sobre la innovación en Colombia*, pp. 175-210.

Silva, M. J., Leitao, J. & Raposo, M., 2008. Barriers to innovation faced by manufacturing firms in Portugal: how to overcome it for fostering business excellence? *International Journal of Business Excellence*, 1(1-2), pp. 92-105.

Teece, D. J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy*, 15(6), pp. 285-305.

Tourigny, D. & Le, C. D., 2004. Impediments to innovation faced by Canadian manufacturing firms. *Economics of Innovation and New Technology*, 13(3), pp. 217-250.

Ullah, F., Abbas, Q. & Akbar, S., 2010. The relevance of pecking order hypothesis for the financing of computer software and biotechnology small firms: Some UK evidence. *International Entrepreneurship and Management Journal*, 6(3), pp. 301-315.

Verspagen, B., 2005. Innovation and Economic Growth. En: J. Fagerberg, D. Mowery & R. Nelson, edits. *The Oxford handbook of innovation*. New York: Oxford University Press, pp. 487-513.

Villa, J. M., 2016. DIFF: Stata module to perform Differences in Differences estimation. Statistical Software Components.

Wallsten, S. J., 2000. The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research program. *The RAND Journal of Economics*, pp. 82-100.

Wanzenböck, I., Scherngell, T. & Fischer, M., 2013. How do firm characteristics affect behavioral additionalities of public R&D subsidies? Evidence for the Austrian transport sector. *Technovation*, 33(2-3), pp. 66-77.

World Federation of Exchanges, 2016. WFE Report on SME Exchanges, Washington: World Bank Group.

ADENDA A LA TESIS

Universidad Autónoma de Madrid

Doctorado en Economía y Gestión de la Innovación

Facultad de Ciencias Económicas y Empresariales

Essays on market failures and finance of innovation in Spain and Colombia

Edgard Alberto Méndez Morales

Directores: Asunción López López y Juan Carlos Salazar Elena

Madrid, Junio 2017

Capítulo 1. Introducción

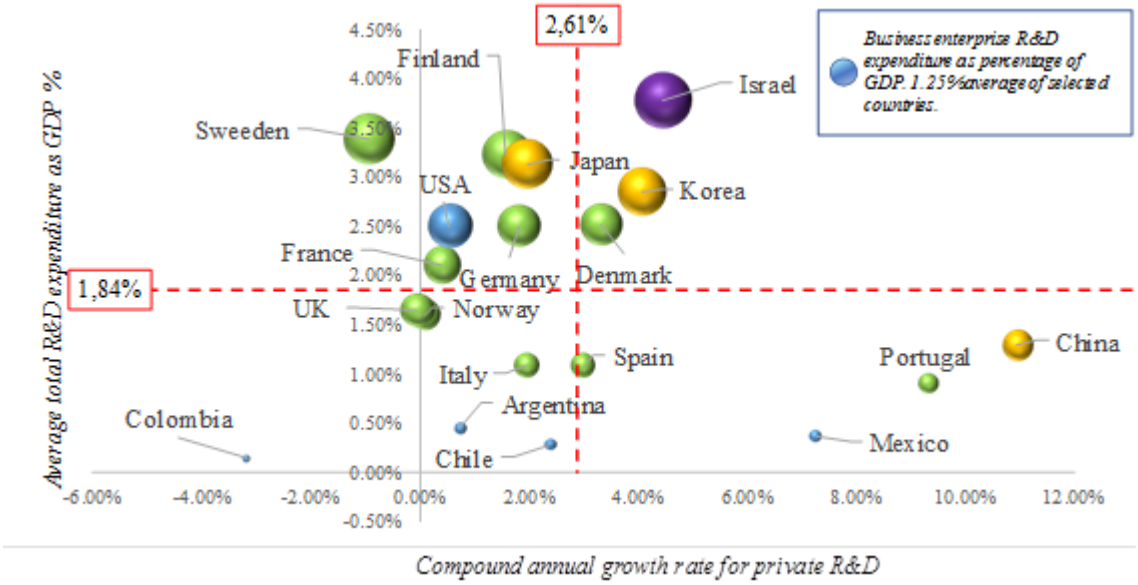
Desde sus orígenes, las ciencias económicas se han preocupado sobre las mejores estrategias necesarias para generar crecimiento económico tanto en los países como en las regiones. La aproximación neo-shumpeteriana basada en las características evolutivas de los mercados ha creado una explicación heterodoxa (aunque no nueva) del crecimiento económico generado por el motor de la innovación al interior de las empresas.

De esta manera, el crecimiento económico se genera en las empresas cuyo principal objetivo es incrementar sus ganancias desarrollando nuevas formas de producción y de procesos relacionados con esa producción (Nelson, 1959; Nelson & Winter, 1982; Verspagen, 2005). Según la literatura de economía evolucionista, el mecanismo que vincula el crecimiento económico con la innovación es la productividad (Nelson, 1959). En consecuencia, Griliches (1988) demostró que los gastos en Investigación y Desarrollo (I+D) elevan la productividad de los países y,por ende, tiene un impacto importante en el crecimiento a largo plazo de las economías mundiales; Griliches (1988) presenta evidencia de la relación entre la disminución de la productividad laboral en los años 70's y una reducción simultánea de los gastos en I+D en Estados Unidos. De manera similar, Brown et al. (2009) muestra que existe una conexión entre inversiones privadas en I+D y el crecimiento económico que sugiere que el auge de las inversiones en I+D de los años 90's contribuyó al crecimiento en la productividad laboral en la economía de Estados Unidos.

Teniendo en cuenta esta evidencia, es posible inferir que las inversiones en I+D deberían ser un proceso extendido en todas las regiones del mundo, especialmente en aquellas menos desarrolladas, dado que este tipo de inversión les permitiría generar el crecimiento que las lleve a igualar a las economías desarrolladas. Sin embargo, aún existen importantes diferencias en los gastos en I+D entre países. Para tratar de superar dichas diferencias los gobiernos alrededor del mundo han establecido políticas de innovación dirigidas a elevar los gastos de I+D en el pasado reciente. Un ejemplo de estas políticas es la estrategia Horizonte 2020 desarrollada por la Unión Europea (UE), en la cual una de sus principales metas es elevar el gasto en I+D a 3% del producto interno bruto (PIB) de la UE; otro ejemplo es la estrategia del gobierno colombiano de elevar el gasto en I+D hasta el 1% del PIB (De Sabios, 1996). Sin embargo, a la fecha, estas cifras no se han alcanzado.

En la Figura 1 se presenta una selección de diecinueve (19) países. En el eje de las abscisas se observa el crecimiento anual compuesto de las actividades privadas en I+D (1996 - 2014), el eje de las ordenadas muestra el promedio de I+D total como porcentaje del PIB (1996 - 2014) y el tamaño de las burbujas representa el promedio de la inversión privada total en I+D como porcentaje del PIB (1996-2014). Existen grandes diferencias entre países; por ejemplo, la mayoría de países nórdicos, Israel, Japón, Corea y Estados Unidos tienen gastos totales en I+D mayores que la media (1,84%). Adicionalmente, México, Portugal, China, España, Dinamarca y Corea están aumentando sus gastos privados de I+D a una velocidad mayor que el promedio de los países seleccionados (2,61%). Algunas economías como las de Chile, Argentina, Colombia e Italia tienen menores promedios de gastos totales y privados en I+D y una tasa de crecimiento anual negativo del 3,15%. A este ritmo, las diferencias estructurales de I+D entre países como Colombia, Chile, Argentina e Italia frente al desarrollo de países como Israel, Corea y otros, se incrementará en el largo plazo.

Figura 1. Gasto total en I+D de países seleccionados (1996-2014)



Fuente: UNESCO. Chile (2007-2014), México (1996-2011), Noruega (1997-2014), Suecia (1997-2014), y Estados Unidos (1996-2013)

El hecho de que los países latinoamericanos (Colombia, Chile, Argentina y México) muestran gastos y crecimientos en I+D bajos, mientras que en otros países como Israel, Corea o Dinamarca estos niveles son altos, lleva a examinar las causas de dichas diferencias entre países. A primera vista, las dimensiones de las burbujas en la Figura 1 entregan algunas pistas sobre un fenómeno crítico relacionado con la I+D (i.e. el monto privado en gasto en I+D de cada país). Los países con

los gastos más bajos en I+D como Colombia, Chile, Argentina o México, tienen a su vez bajos gastos privados en I+D. En la Figura 2 se muestra una comparación de los gastos en I+D de dichos países seleccionados. En países como Colombia, Chile, México o Argentina, la participación de las empresas privadas en el gasto total en I+D es mínima, y Colombia tiene el menor nivel de todos los países seleccionados con 32% del total de gasto en I+D. Adicionalmente, los países en los cuales el total de gasto en I+D está por encima del promedio, presentan altos niveles de participación privada en dichos gastos; países como Corea, Japón, Finlandia, Suecia o Israel presentan niveles privados superiores al 70% del total de gastos en I+D.

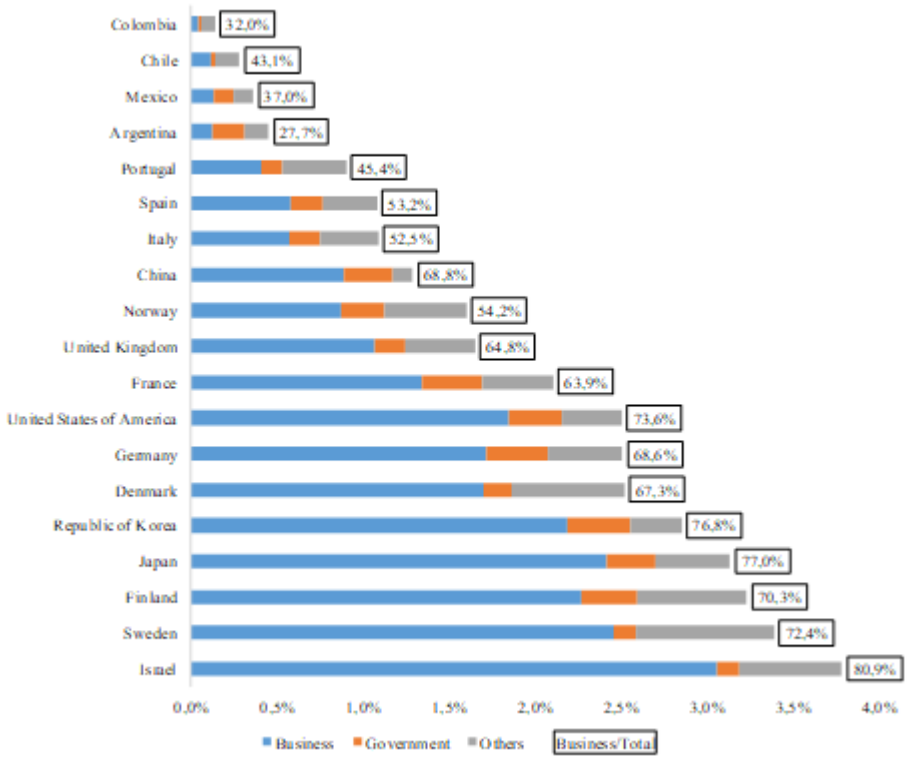
El hecho de que los países latinoamericanos (Colombia, Chile, Argentina y México) muestran gastos y crecimientos en I+D bajos, mientras que en otros países como Israel, Corea o Dinamarca estos datos son altos, lleva a examinar las causas de dichas diferencias entre países. A primera vista, las dimensiones de las burbujas en la Figura 1 entregan algunas pistas sobre un fenómeno crítico relacionado con la I+D (i.e. el monto privado en gasto en I+D de cada país). Los países con los gastos más bajos en I+D como Colombia, Chile, Argentina o México, tienen a su vez bajos gastos privados en I+D. En la Figura 2 se muestra una comparación de los gastos en I+D de dichos países seleccionados. En países como Colombia, Chile, México o Argentina, la participación de las empresas privadas en el gasto total en I+D es mínima, y Colombia tiene el menor nivel de todos los países seleccionados con 32% del total de gasto en I+D. Adicionalmente, los países en los cuales el total de gasto en I+D está por encima del promedio, presentan altos niveles de participación privada en dichos gastos; países como Corea, Japón, Finlandia, Suecia o Israel presentan niveles privados superiores al 70% del total de gastos en I+D.

En ese orden de ideas, es posible argumentar que bajos montos de gasto privado en I+D están relacionados con un nivel bajo de inversión total en I+D a nivel nacional. Todavía no entendemos completamente las razones detrás de estos bajos niveles de inversión privada en I+D, o que causa dichas diferencias entre países, sin embargo, en el último siglo la literatura se ha enfocado en algunas explicaciones razonables para este fenómeno.

En primer lugar, existen factores que obstaculizan la inversión de las empresas en actividades de I+D. Este problema ha sido investigado desde los trabajos seminales de Nelson (1959) y Arrow (1962); en general para Nelson y Arrow, la inversión privada en I+D es altamente riesgosa desde el punto de vista financiero debido principalmente a que requiere altos niveles de flujo de caja, es una inversión costosa, de largo plazo, incierta y en algunos casos, sus resultados son intangibles. Dichos

factores son causados por fallas de mercado como la presencia de información asimétrica y la imposibilidad de la apropiación total de sus resultados innovadores por parte de las empresas; dichas fallas de mercado incrementan el riesgo y por tanto el costo de los proyectos de innovación en relación a los proyectos basados en activos tradicionales (Hall & Lerner, 2010).

Figura 2. Gasto total en I+D por sector de ejecución (1996-2014)



Fuente: UNESCO. Chile (2007-2014), México (1996-2011), Noruega (1997-2014), Suecia (1997-2014), y Estados Unidos (1996-2013). Otros incluyen organizaciones sin ánimo de lucro y universidades.

Por lo tanto, las empresas que tratan de implementar actividades de innovación enfrentan fuertes impedimentos cuando tratan de recaudar dinero de fuentes internas y externas. En primer lugar, las fuentes internas de financiación son escasas y en algunas ocasiones el flujo de caja debe ser utilizado para cubrir otros tipos de gastos, especialmente si la compañía tiene restricciones de caja, como es usual en el caso de compañías pequeñas y jóvenes (Hall & Lerner, 2010). Adicionalmente, las empresas innovadoras que intentan captar recursos de fuentes externas enfrentan altos costos financieros directos y costos hundidos dada la naturaleza intangible de la innovación y sus características inciertas. Por lo tanto, todos aquellos factores que determinan la forma en que las

empresas innovadoras financian sus gastos en Investigación, Desarrollo e Innovación (I+D+i) deberían ser comprendidos para generar políticas óptimas que permitan elevar el gasto de las empresas en I+D, especialmente en el caso de empresas, países y regiones con bajas actividades de innovación como aquellos incluidos en la Figura 1. En años recientes, se ha hecho énfasis en el estudio de dichas fallas por parte de los investigadores en barreras a la innovación utilizando encuestas de innovación.

En segundo lugar, algunos académicos han propuesto que las diferencias en los niveles de gasto en innovación en los países, como aquellos presentados en la Figura 1 y Figura 2, pueden deberse a las diferentes mezclas y relaciones organizacionales e institucionales presentes en mercados innovadores en todos los países. Para economías en las que el gasto en I+D es bajo, es consistente pensar que el desarrollo de organizaciones sólidas que respalden la innovación es necesario, en ese sentido, una de las funciones principales de aquellas organizaciones e instituciones es facilitar la vía en que las empresas y de manera general, los mercados, perciben y enfrentan las barreras a la innovación. Esta aproximación académica se inició con los trabajos seminales de Freeman (1987), Lundvall (1992) y Nelson (1993); para Freeman estas relaciones se enmarcan en lo que se conoce como el Sistema Nacional de Innovación (SNI), que él define como "la red de instituciones en los sectores público y privado cuyas actividades e interacciones inician, importan, modifican y difunden nuevas tecnologías".

De la misma manera, Edquist (2010), propone que una de las actividades fundamentales del SNI es la financiación de actividades privadas de innovación facilitando la comercialización y adopción de tecnologías; para países con bajas cantidades de gasto en I+D privado, es posible que algunos de los marcos institucionales y organizacionales ya desarrollados en países como Israel, Corea y otros países no estén completamente desarrollados. En ese sentido, los investigadores han tratado de descubrir las complejidades de la relación entre los impedimentos, la financiación y el marco institucional de la innovación, tratando de entender las causas que están detrás de las diferencias en gasto en I+D alrededor del mundo. A ese respecto, desde Schumpeter se ha argumentado que la relación entre innovación y sus enramados financieros es fundamental para entender los ciclos económicos y el desarrollo:

> La relación lógica (...), entre lo que es llamado "creación de crédito por parte de los bancos" y la innovación, no se perderá de nuevo. Esta relación, que es fundamental para el

> entendimiento del motor capitalista, es la base de todos los problemas de dinero y crédito, dado que no son simples problemas de finanzas públicas (Schumpeter, 1939, p. 111).

Adicionalmente, Schumpeter entendió que hay algunos problemas con la relación entre mercados financieros e innovación creados por las asimetrías en la información, y que estas fallas hacen que las organizaciones de los mercados financieros malinterpreten el fenómeno de la innovación:

> ...El fracaso de la comunidad bancaria para funcionar en la forma requerida por la estructura de la máquina capitalista genera la mayor cantidad de eventos que la mayoría de observadores denominan "catástrofes". Es apenas natural que como dichas fallas se muestran en primera instancia cuando se trata de propuestas innovadoras -en donde juzgar adecuadamente es difícil y la tentación es fuerte- se ha desarrollado una asociación entre la financiación de la innovación y el rechazo o mala práctica que, aunque es entendible, no facilita el análisis (Schumpeter, 1939, pp. 117-118).

Sin embargo, a pesar de que gran número de esfuerzos se han hecho en el último siglo para entender las barreras a la innovación, los engranajes financieros y el marco de la innovación, e incluso ahora cuando existen microdatos disponibles para investigar este problema, es todavía difícil para las empresas, la academia y los responsables de la política, comprender el fenómeno de la financiación a inversión de la innovación a fondo. Por lo tanto, las empresas aún enfrentan fallas que impiden el gasto en I+D privado y desaceleran el ritmo de la productividad, y los países aún necesitan implementar un marco institucional que respalde la financiación de innovación privada, especialmente en economías subdesarrolladas.

La literatura relacionada con la financiación de la innovación nos ha hecho saber que las empresas innovadoras jóvenes, pequeñas y de alta tecnología tienden a enfrentar impedimentos a la innovación en una proporción superior que sus contrapartes; adicionalmente, la evolución de los mercados financieros ha servido para la creación de instrumentos como el capital de riesgo e instituciones como mercados de valores para pequeñas empresas como una forma de superar los impedimentos de las compañías innovadoras y de rápido crecimiento. Sin embargo, estos instrumentos e instituciones son altamente especializadas y no están disponibles para todas las empresas, especialmente en mercados emergentes en donde el número de empresas dedicadas a la inversión en capital de riesgo o el número de ángeles inversionistas es mínimo. Es en ese sentido en

que la aproximación a los SNI de Edquist (2010) es relevante (i.e. es necesario crear y desarrollar instrumentos e instituciones financieras que respalden la actividad innovadora).

De igual forma, aunque la literatura ha revelado algunas pistas sobre la forma en que las grandes empresas transadas en bolsas de valores financian sus proyectos de innovación, todavía no entendemos totalmente cómo las fallas de mercado y los impedimentos a la innovación forjan la estructura de capital de las empresas más pequeñas que no son transadas de forma pública. De tal forma, para las empresas que enfrentan fuertes impedimentos a la innovación, los gobiernos alrededor del mundo han desarrollados instrumentos financieros como subsidios con la finalidad de incrementar la actividad innovadora y generar efectos positivos de "derramamiento" (*spill-over effects*) en los mercados. Sin embargo, aún no entendemos totalmente los efectos que estos instrumentos tienen en el comportamiento de largo plazo de las empresas innovadoras.

Múltiples dudas adicionales permanecen sin responder en el marco de la relación financiación-innovación. Esta tesis es un pequeño esfuerzo para incrementar el conocimiento sobre este fenómeno usando microdatos de empresas localizadas en España y Colombia; en general, esta investigación se enfoca en una amplia pregunta de investigación: ¿cuáles son las fuentes de financiamiento y las particularidades innovadoras de las pequeñas empresas innovadoras que enfrentan impedimentos a la innovación?

De igual forma, esta investigación trata de responder algunas preguntas de investigación específicas que serán respondidas en cada uno de los siguientes capítulos:

Capítulo 2:

- ¿En qué fase del proceso innovador las pequeñas empresas tienden a percibir impedimentos financieros, de conocimiento y de mercado relacionados con el fenómeno innovador?
- ¿Cuáles son los impedimentos percibidos por las empresas que ya se benefician de los resultados de la innovación?

Capítulo 3:

- ¿Cuáles son las principales características de las empresas financiando sus actividades innovadoras a través de fuentes de fondos internas, bancos, fuentes de capital y fuentes públicas?

- ¿Cómo puede caracterizarse la estructura de capital de empresas que realizan actividades de innovación en un país subdesarrollado como Colombia?

Capítulo 4:

- ¿cuáles son los impactos de largo plazo de los subsidios concedidos por el gobierno en las variables de entrada y salida de innovación de las empresas?
- ¿Cuál es el efecto de largo plazo de la recurrencia de los subsidios a la innovación en los resultados innovadores de las compañías?

Proveer respuestas para estas preguntas es fundamental desde el punto de vista de la política dado que permitirá el desarrollo de mejores medidas de intervención, organizaciones e instituciones para que las empresas puedan sobreponerse a los impedimentos de la innovación, financiar proyectos de innovación más eficientemente y como resultado, generar conocimiento, productos y procesos innovadores más eficientemente y en el largo plazo, generar crecimiento económico. Específicamente esta investigación trata sobre el efecto de los impedimentos a la innovación, la financiación de la innovación y los subsidios públicos en pequeñas y medianas Vs. grandes empresas, dado que las primeras tienden a percibir las fallas de mercado en mayor proporción (Hall & Lerner, 2010).

Datos y metodología

Recolectar datos sobre la actividad innovadora y el comportamiento financiero de las empresas innovadoras no es una tarea fácil, y recolectar dicha información de manera que sea comparable es aún más difícil. Sin embargo, desde el inicio de los años 90 algunos países han desarrollado la titánica tarea de reunir información sobre las actividades de innovación al nivel de la empresa como una medida para generar mejores indicadores de innovación que los típicos usados en los años 70 y 80. En este sentido, en 1992 la Organización para la Cooperación y el Desarrollo Económico (OCDE) emitió el Manual de Oslo; este documento fue desarrollado para dos metas principales, proveer una guía para crear, medir y comparar indicadores de innovación al interior de los miembros de la OCDE y discutir los problemas analíticos para los cuales esos indicadores son relevantes (OECD, 1997).

Siguiendo las directrices del Manual de Oslo, la UE desarrolló la Encuesta de Innovación Comunitaria (Community Innovation Survey - CIS) como un esfuerzo a gran escala para comparar las variables de entrada y de salida de las actividades de innovación de las

empresas de la UE (Arundel & Smith, 2013), y desde el año 2004 esta encuesta ha sido aplicada cada dos años. Un caso especial de la CIS es el Panel de Innovación Tecnológica (PITEC). Esta encuesta desarrollada por el gobierno español es llevada a cabo de forma anual y es accesible de manera libre. Para el propósito de esta investigación la base de datos de PITEC ha sido usada en el capítulo 2 (2003-2013) en un intento por medir la percepción de impedimentos de innovación de pequeñas y medianas empresas (Pymes) y en el capítulo 4 (2007-2013) para medir los impactos de los subsidios de innovación en la actividad innovadora de las compañías españolas.

Siguiendo las actividades de las encuestas de innovación de la UE, otras regiones del mundo han desarrollado sus propias encuestas de innovación basadas en los criterios del Manual de Oslo, especialmente en Latinoamérica (Salazar & Holbrook, 2004). En ese sentido, debe prestarse especial atención a los ejercicios desarrollados en países como México, Chile, Argentina, Uruguay, Ecuador o Colombia. En el caso de Colombia, se han desarrollado dos encuestas, la primera para empresas de manufactura (EDIT-Encuesta de innovación tecnológica) y la segunda para empresas del sector comercio y servicios (EDITS). Estas encuestas han sido llevadas a cabo desde el año 2005 y 2006 respectivamente; para el caso específico de esta investigación, la EDIT entre los años 2008 y 2009 fue utilizada en el capítulo 3 para determinar las fuentes de financiación que las empresas innovadoras colombianas usan para financiar sus proyectos de innovación.

Las metodologías usadas en esta investigación fueron modelos probit de panel, modelos probit multivariados y modelos de diferencia en diferencia condicionada (CDID); cada una de estas metodologías fue usada para superar algunas problemáticas y ventajas de los datos usados. Adicionalmente, algunas limitaciones de esta investigación se desprenden de los datos y las metodologías escogidas. En primer lugar, en el caso de Colombia, sólo una ola de la EDIT estuvo disponible aun cuando existen múltiples olas de esta encuesta; el acceso limitado a las salas de acceso seguro en la oficina del Departamento Nacional de Innovación (DANE) en Bogotá y las restricciones sobre la transferencia internacional de los datos no permitió el acceso a otras olas de la encuesta. Aún más, los datos de la EDIT entre 2008 y 2009 no permiten el acceso a variables de salida empresarial como las ventas, que

habrían sido valiosas como forma de referencia cruzada sobre el comportamiento financiero de las compañías. De igual forma, en el caso de los efectos de largo plazo de los subsidios públicos de innovación de las empresas españolas, la metodología CDID utiliza una aproximación lineal para medir el comportamiento innovador de las empresas, de tal forma, variables de comportamiento empresarial (*Behavioral*) como la cooperación, propensión a innovar y patentar son medidas por PITEC como variables binarias o de conteo; de tal forma, no fue posible verificar si existen efectos de largo plazo en variables de comportamiento de las empresas innovadoras.

Esta tesis está organizada de la siguiente forma. En el capítulo 2 se incluye una investigación sobre la percepción de los impedimentos a la innovación para Pymes de manufactura españolas para los años 2005 a 2013. Este capítulo trata de develar la forma en que los impedimentos a la innovación actúan sobre las empresas durante el proceso innovador desde una perspectiva dinámica; en ese sentido, se presta especial atención a las formas que toman las fallas de mercado a través de la percepción de impedimentos a la innovación de las empresas desde el principio hasta el fin del proceso de innovación empresarial. En el capítulo 3 se presenta una investigación que trata sobre las fuentes de financiación y la estructura de capital de las empresas innovadoras colombianas; específicamente este capítulo muestra los efectos que las fallas de mercado tienen en el acceso a fuentes de financiación como flujo de caja, bancos, capital y subsidios públicos en un país con un mercado financiero subdesarrollado y con la estructura de los mercados de capital en países en vía de desarrollo. En el capítulo 4, y dado que las empresas que enfrentan una mayor proporción de fallas de mercado tienden a tener baja inversión en I+D, se desarrolla una investigación sobre los efectos de largo plazo que tienen los subsidios de innovación en compañías españolas. En este capítulo se presta especial atención en los efectos que dichos subsidios tienen en variables de entrada y salida del proceso innovador y en el tamaño de la empresa como una variable fundamental para determinar dichos efectos. Finalmente, en el capítulo 5, se presentan las conclusiones generales de la tesis, los impactos en términos de política y propuestas para una futura agenda de investigación.

La forma funcional que se le dio a esta tesis, separada en tres capítulos con objetivos y preguntas de investigación diferentes pero relacionadas entre sí, tiene como objetivo el sometimiento de corto plazo de estos capítulos a revistas revisadas por pares académicos una vez que la tesis sea aprobada. Adicionalmente, aunque mi función en todos los capítulos fue la de investigador principal, los coautores de los capítulos 2 y 4 son Juan Carlos Salazar y Asunción López López de la Universidad Autónoma de Madrid y quiero darles crédito. Para el capítulo 3 recibí valiosas contribuciones de Florentino Malaver y Marisela Vargas de la Pontificia Universidad Javeriana, especialmente en cuanto a factores relacionados con la recolección de datos. Aun cuando valoro de gran forma la colaboración de estas personas en el desarrollo de la tesis, los errores presentes en la misma son de mi entera responsabilidad.

Capítulo 5: Conclusiones e implicaciones de política

Una manera de poner de manifiesto las deficiencias en los mercados y en el Sistema Nacional de Innovación (SNI) a las que se enfrentan las empresas innovadoras y los países, es a través de las diferencias en gasto en I+D presentadas en el Capítulo 1; las inversiones en I+D de las empresas privadas tienden a ser más bajas en países menos desarrollados. Por lo anterior, uno de los principales objetivos de la los gobiernos y la academia debería ser la implementación de un conjunto de políticas e instrumentos enfocados en el incremento del gasto de empresas privadas en I+D, especialmente en países en vía de desarrollo para generar desarrollo de largo plazo.

La tradición neo-Schumpeterianna y de la economía evolutiva han investigado este fenómeno desde sus inicios y algunos efectos políticos son visibles ahora; por ejemplo, alrededor del mundo el concepto de SNI ha sido adoptado por los responsables de políticas con el fin de entender las diferencias entre el desempeño de los mercados innovadores y las formas en las que esos sistemas pueden apoyar empresas y organizaciones en superar impedimentos a la innovación (Edquist, 2010). Sin embargo, estamos lejos de tener un completo entendimiento de los efectos de las fallas de mercado en las actividades innovadoras de las empresas y del diseño de un grupo de políticas y de un marco institucional para superar dichas fallas. En ese sentido, esta tesis aborda el fenómeno de las fallas de mercado y cómo éstas afectan las actividades de innovación y las fuentes de financiación de las Pymes en España y Colombia. La idea principal detrás de esta tesis era responder a la pregunta de investigación: ¿cuáles son las fuentes de financiación y las particularidades innovadoras de empresas innovadoras pequeñas que enfrentan barreras para la innovación?

En el segundo capítulo, utilizando datos para Pymes españolas entre el año 2005 y 2013, se mostró que la percepción de impedimentos a la innovación es particularmente fuerte en las Pyme; estas empresas tienden a fallar en sus proyectos de innovación debido a un conjunto diverso de impedimentos. Sin embargo, hasta ahora, no se había prestado atención al

proceso completo de innovación relacionado a esta percepción y la literatura tiende a ignorar el hecho que las empresas se involucran en proceso de innovación para obtener beneficios económicos y se enfoca solamente en la fase de invención desde la cual todavía falta un largo camino para la innovación.

En ese sentido, se realizó una separación entre los estadios de invención y comercialización para determinar si existen diferencias en la percepción de impedimentos a la innovación en dichas fases. Los resultados muestran que las empresas tienden a percibir impedimentos de conocimiento y económico/financieros en la fase de invención. Sin embargo, el fracaso en la fase de comercialización de las invenciones es caracterizada por la percepción de impedimentos de mercado (i.e. relacionados con competencia e incertidumbre). Las empresas que exitosamente completan el proceso de innovación (i.e. venden productos y servicios innovadores) no perciben impedimentos a la innovación, ergo, las empresas que obtienen beneficios en ventas de la innovación son aquellas que pueden superar dichos impedimentos.

Las implicaciones de gestión para las empresas de estos resultados son importantes. Primero, las empresas que se encuentran en una fase de invención necesitan asegurar la llegada de fondos de financiación para sobreponerse exitosamente a dicha fase del proceso de innovación y por tanto, obtener rentabilidades en el futuro cercano (los capítulos 3 y 4 se basan en esa implicación investigando las formas en que las empresas financian sus iniciativas de innovación a través de fuentes privadas y el efecto de la financiación pública de la innovación al interior de las empresas). Al mismo tiempo, las empresas deben resolver su vacío de trabajadores con conocimiento especializado para obtener buenos resultados en la fase de invención, es decir, necesitan personal especializado capaz de entender completamente las complejas implicaciones de los proyectos de innovación.

Dado que las empresas con invenciones tienden a percibir la competencia e incertidumbre (impedimentos de mercado) como sus principales inconvenientes, estas empresas deben estar preparadas para competir con empresas consolidadas, con más recursos y más experiencia si quieren sobrevivir en los mercados. Al mismo tiempo, estas empresas

podrían reducir la incertidumbre usando metodologías establecidas de tiempo atrás como son la vigilancia tecnológica y competitiva o el pronóstico por medio del análisis prospectivo.

Las implicaciones de política de dichos resultados son también interesantes; el hecho de que las empresas en el estadio de comercialización tienden a percibir únicamente impedimentos de mercado muestra que los tomadores de decisiones de políticas en los gobiernos podrían desarrollar políticas más adecuadas para disminuir las fallas de mercado relacionadas con la competencia desleal y los monopolios desregulados. De igual forma, dado que las empresas que ya obtienen ingresos de productos y servicios innovadores tienden a no percibir ningún tipo de impedimentos, muestra que los gobiernos deberían desarrollar políticas dirigidas a disminuir todos los impedimentos de la innovación si quieren generar un conjunto completo de efectos de derramamiento que impacten a los mercados. De la misma forma, los encargados de política deberían reforzar la creación de organizaciones e instituciones relacionadas con la generación de trabajadores de alto conocimiento para apoyar a las empresas que se encuentran en las fases de invención (i.e. reforzamiento del sistema de educación como una forma para apoyar a las empresas para superar los impedimentos a la innovación).

En el capítulo 3 y usando datos para Colombia, se encontró que las pequeñas empresas tienden a tener un menor acceso a bancos y a financiación de capital para respaldar sus proyectos innovadores que las grandes empresas. De tal forma, este tipo de compañías tienden a usar fondos internos y subsidios gubernamentales para financiar dichas actividades. De igual forma, las empresas que tienen una alta proporción de gastos en innovación dirigidos a la compra de activos intangibles tienden a tener menor acceso a préstamos bancarios. En consecuencia, las empresas con alta generación de activos intangibles dentro de su proceso de innovación tienden a tener menores probabilidades de ser financiadas mediante recursos bancarios.

Los resultados del capítulo 3 también pueden ser contrastados frente a la literatura que respalda la hipótesis de una estructura de capital basada en un Orden Jerárquico Alterado

(Altered Pecking Order) para financiar sus proyectos de innovación. Se propone que estos resultados son consecuencia de un mercado financiero subdesarrollado que disminuye la posibilidad de las firmas de usar fuentes de capital como fuentes de fondos para la innovación. En relación a este último punto, la financiación para hacer innovación respaldada por el gobierno es más probable que la financiación respaldada con fuentes de capital. Este hecho es perturbador dado que las agencias gubernamentales colombianas relacionadas con ciencia tecnología e innovación tienen bajos presupuestos para subsidiar la inversión de empresas privadas y dado el hecho que las exenciones impositivas han sido concedidas en su gran mayoría a grandes empresas (79%) en décadas pasadas (Departamento Nacional de Planeación, 2015). En este sentido, las Pymes en Colombia usan flujo de caja para financiar sus proyectos de innovación dado que no tienen acceso a otras fuentes de financiación. De tal forma, las cifras de los gastos en innovación exhibidas en las Figura 1 y Figura 2 pueden estar relacionadas con el desarrollo del sistema financiero colombiano y con la baja cifra de ayudas gubernamentales para la innovación desde el gobierno colombiano.

Existen otras implicaciones de los resultados del Capítulo 3; desde el punto de vista de la gestión de la innovación, el hecho que los activos intangibles tengan una relación negativa con el acceso a capital externo es una oportunidad para las compañías e instituciones financieras para desarrollar una relación basada en un sistema armonizado de reportes que muestren los valores y formas de gestionar el capital intelectual al interior de las Pymes. Algunos esfuerzos sobre este tema se han desarrollado en años recientes, especialmente con la creación del Informe de Capital Intelectual realizado en Europa (Incas), que es un reporte que busca sistematizar el conocimiento embebido al interior de las organizaciones como una fuente de información para la gestión estratégica y para reducir las asimetrías de información con las instituciones financiadoras e inversionistas (Mertins & Will, 2007; Sánchez, et al., 2012). El surgimiento de este tipo de metodologías hará que el acceso a fuentes externas de financiamiento por parte de las Pymes sea menos restringido. Sin embargo, en Colombia por lo que se sabe, no existen aún esfuerzos para implementarlas.

Las implicaciones de política de estos resultados son también interesantes. Dado que las Pymes son las empresas que enfrentan en mayor proporción las dificultades de acceso a fuentes externas de financiamiento para proyectos innovadores, los gobiernos deberían desarrollar estrategias para facilitar el acceso a dicho capital, especialmente en países como Colombia en donde los presupuestos públicos para la I+D han venido recortándose en años recientes. En ese mismo orden de ideas, el desarrollo de bolsas de valores para Pymes puede ser una política de mediano plazo para dar acceso a las empresas a capital en el largo plazo. En ese sentido, el mercado KOSDAQ creado en 1996 en Corea, la Bolsa TSX Venture desarrollada en Canadá en 1999 y el Mercado Alternativo de Inversiones (AIM) creado en 1995 en Londres son los paradigmas dignos de seguir (World Federation of Exchanges, 2016). Para permitir la creación de dichos mercados es necesario que los gobiernos apliquen mayor flexibilidad en la regulación sobre las Pymes y sus ofertas públicas iniciales (IPOs) y que respalden la creación de dicho tipo de mercados dentro de los existentes actualmente; al mismo tiempo, la creación de políticas para que las empresas de estos mercados reporten también su capital intelectual, como se propuso en el párrafo anterior, puede ser útil para disminuir los costos de agencia de recaudar capital por medio de las bolsas de valores. Desde el punto de vista teórico, esta idea se relaciona con la propuesta de Edquist sobre el fortalecimiento de los SNI por medio del desarrollo de un mejor entramado organizacional e institucional para financiar la innovación.

Al mismo tiempo, el acceso de las Pymes a fuentes externas de financiación está restringido en relación a los bancos; la literatura revisada y los resultados empíricos del Capítulo 2 soportan la idea de que los costos financieros de la innovación es alto en relación a otros tipos de inversiones empresariales, de tal manera, una política que los gobiernos de todo el mundo podrían utilizar para superar parcialmente esta problemática es la del desarrollo de un subsidio de tasa de interés para proyectos innovadores. En muchas economías alrededor del mundo, el subsidio de tasa de interés a las hipotecas es una política para mejorar el acceso a la compra de casa propia como una manera de proveer externalidades positivas a la economía. La forma práctica de implementar dicho subsidio es el cubrimiento de uno a cuatro puntos porcentuales del interés hipotecario para las familias. Dado que el gasto en innovación también crea efectos de derramamiento y externalidades positivas en los

mercados, una política para reducir la tasa de interés que enfrentan las empresas innovadoras en los mercados bancarios podría elevar el nivel de gasto privado en I+D y los efectos de derramamiento en la economía.

Dado que las Pymes enfrentan muchas fallas de mercado e impedimentos a la innovación y que dichas empresas necesitan superar dichas fallas e impedimentos para generar ingresos en sus proyectos innovadores (Capítulo 2), pero al mismo tiempo, las Pymes tienden a tener restricciones para acceder a fuentes externas de financiación (Capítulo 3), lleva a pensar que la estrategia gubernamental de otorgar subsidios a las Pymes puede ser una buena aproximación.

En relación con esta última idea y usando datos de empresas españolas en el periodo 2005-2013, en el Capítulo 4 se realizó una investigación sobre el impacto de los subsidios de innovación en variables de innovadoras de entrada y salida en el largo plazo. Los resultados de esta investigación muestran que las Pymes no presentan un efecto de desplazamiento de su inversión en I+D (Crowding-out effect). Más aún, las Pymes muestran un efecto de complementariedad frente a dichos subsidios. Al mismo tiempo, las capacidades de absorción de las empresas, medidas por medio del gasto externo en I+D, tienen incrementos positivos luego de la recepción de subsidios. En la misma dirección, el reclutamiento de empleados en I+D se incrementa en el largo plazo a causa de los subsidios. Simultáneamente, en el Capítulo 4 se mostró que la recurrencia de los subsidios incrementa los efectos en la adicionalidad de dichas variables, por lo tanto, las empresas que reciben subsidios esporádicamente tienen a presentar menores impactos que las empresas que reciben subsidios de forma recurrente.

Las implicaciones en la gestión empresarial de dichos resultados son atractivas; dado que los impedimentos de conocimiento son importantes en la fase de invención de las empresas (Capítulo 2), el hecho de que los subsidios en el largo plazo incrementan la capacidad de las empresas para contratar empleados de I+D podría llevar a éstas a aplicar a subsidios para solucionar no solo los impedimentos económicos/financieros sino también los de conocimiento. Al mismo tiempo, dado que las capacidades de absorción de las empresas

tienden a expandirse con el tiempo, especialmente si las empresas reciben subsidios recurrentes, las empresas menos experimentadas en desarrollar sus propios proyectos deberían aplicar a subsidios con la finalidad de adquirir I+D externo; en el largo plazo esto podría generar efectos de derramamiento interno y externo para las empresas, sus pares y la sociedad (i.e. una estrategia de "no seleccionar al ganador" puede de alguna manera, disminuir la falta de capacidades de innovación de las compañías).

Simultáneamente, estos resultados pueden ser un estímulo para las empresas que buscan desarrollar proyectos de innovación mediante acuerdos de cooperación con clientes, pares, universidades e instituciones gubernamentales. Si la adquisición de conocimiento externo puede expandir sus capacidades para realizar innovación, el esquema de innovación abierta desarrollado por Chesbrough (2003) como una forma de compartir el conocimiento, también puede ser una forma de superar las barreras de mercado enfrentadas por las Pymes; en ese sentido, políticas dirigidas hacia la implementación de acuerdos de cooperación entre empresas nacionales e internacionales, como el programa Horizonte 2020, deberían ser implementadas en todo el mundo.

Bajo la misma línea de pensamiento, existen otros resultados del Capítulo 4 que son interesantes desde el punto de vista de la implementación de políticas. En primer lugar, el hecho que no pudo probarse una adicionalidad de salida (outcome) con las variables usadas en esta investigación, y dado que la literatura también ha encontrado múltiples dificultades para medir dichas adicionalidades en las variables de salida, puede llevar a la búsqueda de nuevas y mejores variables para ser incluidas en las encuestas de innovación de todo el mundo. Al mismo tiempo, esto podría llevar a llamar la atención de los encargados de política y académicos hacia variables de comportamiento empresarial (behavioral) más ajustadas para evaluar las políticas de subsidios a la innovación o nuevas metodologías para explicar dichos efectos.

Igualmente, el hecho que los efectos de adicionalidad son superiores para las Pymes que para las grandes empresas, enfatiza la idea que los subsidios podrían ser focalizados en empresas que enfrentan impedimentos a la innovación en mayor proporción como las

empresas de reciente creación, al contrario de lo que sucede en Colombia. Por último, aunque no menos importante, una política enfocada en programas de apoyo de largo plazo podría generar mayores impactos económicos que subsidios generados esporádicamente. Sin embargo, los encargados de política deben estar al tanto del tipo de empresas que son financiadas con estas políticas dado que las grandes empresas están mejor preparadas para presentarse y ser financiadas con este tipo de subsidios.

Finalmente, los tres capítulos de investigación que componen esta tesis exponen un buen número de líneas de investigación que podrían ser desarrolladas en el futuro, iniciando con el Capítulo 2, sería interesante determinar cuáles instrumentos de política e instrumentos de gestión son válidos para superar completamente los impedimentos de las empresas que se encuentran en las fases de invención y comercialización del proceso de innovación, especialmente, los relacionados con los impedimentos de conocimiento y de mercado que han sido menos estudiados en el pasado. En ese sentido, el enfoque de la economía abierta parece ser prometedor.

El Capítulo 3 abre un conjunto completo de preguntas de investigación para ser desarrolladas en el futuro próximo. Primero, si los mercados financieros son tan importantes para los proyectos de innovación, ¿cuál fue el impacto de la crisis financiera de 2008 en el flujo de innovación en el mundo? De igual forma, aun cuando existen estudios que concluyen que existe una relación entre la sofisticación de los mercados financieros y la innovación, debería prestarse más atención a los países en vía de desarrollo en donde estos mercados están menos desarrollados. Respecto a esto, el impacto que los mercados de valores de pequeñas empresas en Londres, Toronto y Corea han tenido sobre los resultados de innovación a nivel regional y las formas óptimas en las cuales dichos mercados podrían ser implementados en países en vía de desarrollo, deberían ser investigados desde el punto de vista financiero y de los SNI.

Adicionalmente, una agenda de investigación propuesta por estudios europeos relacionados con la implementación de reportes de capital intelectual como una forma de disminuir la asimetría de información entre inversionistas, podría ponerse en práctica en países en vía de

desarrollo. En el corto plazo implementando estudios de caso de empresas y bancos dispuestas a usar este tipo de información y en el largo plazo, proponiendo el desarrollo de políticas respaldadas a nivel gubernamental para la implementación de este tipo de reportes en países como Colombia.

Para el Capítulo 4, la implementación de estudios que midan la adicionalidad de largo plazo de los subsidios de innovación para variables de comportamiento empresarial como propensión a innovar, cooperación, disponibilidad para la innovación abierta, abandono de proyectos entre otras, puede ser un buen punto de partida para encontrar otro tipo de efectos de los subsidios desde el punto de vista microeconómico.

Finalmente, la gran atención prestada en décadas recientes a la relación entre innovación y desarrollo económico debería llamar nuestra atención para desarrollar una mayor cantidad y una mayor profundidad de esfuerzos para maximizar los niveles de I+D privados, políticas gubernamentales e investigación por parte de la academia relacionadas con el marco de la innovación. Dichos esfuerzos conducirán en el largo plazo no sólo a incrementar el desarrollo económico sino también a disminuir las inequidades sociales.